98TH CONGRESS
2d Session

HOUSE OF REPRESENTATIVES

REPORT
98-629

# AUTHORIZING APPROPRIATIONS TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION FOR FISCAL YEAR 1985

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MARCH 21, 1984.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

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Mr. FUQUA, from the Committee on Science and Technology, submitted the following

## REPORT

together with

## MINORITY VIEWS

[To accompany H.R. 5154]

[Including cost estimate of the Congressional Budget Office]

The Committee on Science and Technology, to whom was referred the bill (H.R. 5154) to authorize appropriations to the National Aeronautics and Space Administration for research and development, space flight, control and data communications, construction of facilities, and research and program management, and for other purposes, having considered the same, report favorably thereon with amendments (shown in italic in the bill accompaning by this report) and recommends that the bill, as amended, do pass.

The amendments are as follows:

The amendments, stated in terms of the page and line numbers of the introduced bill, are as follows:

On page 12, line 1, insert "(a)" after "Sec. 109." and after line 14, insert the following new subsection:

> (b) Section 102(d)(1) of the National Aeronautics and Space Act of 1958, as amended (and as redesignated by subsection (a) of this section), is amended by inserting "of the Earth and" after "knowledge".

On page 14, line 1, strike out "the United States civilian space program" and insert in lieu thereof the following:

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H703-3

The National Aeronautics and Space Administration, the lead civilian space agency, as established in the National Aeronautics and Space Act of 1958, as amended, has conducted a space program that

On Page 14, strike lines 21 through 23, and insert in lieu thereof the following:

(5) the Nation is committed to a permanently manned space station in low earth orbit, and future national efforts in space will benefit from the presence of such a station;

On Page 15, beginning on line 13, strike out "fifteen" and insert in lieu thereof "fourteen" and on line 15, after "subsection" insert the following:

, the Administrator of the National Aeronautics and Space Administration,

On Page 15, line 23, strike out "one of the members to" and insert in lieu thereof:

the Administrator of the National Aeronautics and Space Administration shall

On Page 16, line 1, after "appointed" insert the following: "by the President".

On Page 16, strike lines 20, 21 and 23, and redesignate the succeeding subparagraphs accordingly.

On Page 17, after line 3, add a new subparagraph as follows:

(G) Office of Science and Technology Policy.

On Page 19, before line 1, insert the following new paragraph:

(1) the commitment by the Nation to a permanently manned space station in low earth orbit;

and redesignate the succeeding paragraphs and references thereto accordingly.

On Page 19, line 2, after "environmental" insert "and" and strike out ", and national security".

## PURPOSE OF THE BILL

### TITLE I

The purpose of title I is to authorize appropriations to the National Aeronautics and Space Administration for fiscal year 1985 as follows:

| Programs | Authorization fiscal year 1985 | Page No. |
|---|---|---|
| Research and development | $2,450,100,000 | 7 |
| Space flight, control and data analysis | 3,600,300,000 | 12 |
| Construction of facilities | 150,000,000 | 13 |

| Programs | Authorization fiscal year 1985 | Page No. |
|---|---|---|
| Research and program management..... | 1,331,000,000 | 14 |
| Total..... | 7,531,400,000 | |

## TITLE II

The purpose of title II is to establish a National Commission on Space to assist in the formulation of long range goals for civilian space activity.

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## COMMITTEE ACTIONS

### TITLE I

### RESEARCH AND DEVELOPMENT

#### SPACE TRANSPORTATION CAPABILITY DEVELOPMENT

NASA requested $361,400,000 for space transportation capability development activities in fiscal year 1985. The committee decreased funding for the engineering and technical base activities by $10,000,000 and decreased funding for payload operations and support equipment by $5,000,000 resulting in a total recommended authorization of $346,400,000 in fiscal year 1985.

*Engineering and technical base.* NASA requested $105,700,000 for engineering and technical base activities in fiscal year 1985. The engineering and technical base program provides the core capability required to sustain an engineering and development base for support of the STS development and operations program. Since STS development is nearing completion, a reduction can be sustained in this program with no significant impact. The Committee, therefore, recommends a funding decrease of $10,000,000 resulting in a total authorization of $95,700,000 in fiscal year 1985.

*Payload operations and support equipment.* NASA requested $61,300,000 for payload operations and support in fiscal year 1985. The payload operations and support equipment funding provides for the development and placing into operational status the ground and flight systems necessary to support Space Transportation System payloads during prelaunch processing, on-orbit mission operations, and post-landing processing. Delays in Tracking and Data Relay Satellite (TDRS), Space Telescope, and other payload flight schedules permit a $5,000,000 funding reduction resulting in a total authorization of $56,300,000 in fiscal year 1985.

#### PHYSICS AND ASTRONOMY

NASA requested $677,200,000 for physics and astronomy activities in fiscal year 1985. The Committee increased funding for research and analysis by $6,000,000 and increased funding for Shuttle/Spacelab payload development and mission management by $4,000,000, resulting in a total recommended authorization of $687,200,000 for fiscal year 1985.

*Research and Analysis.* NASA requested $36,900,000 for research and analysis activities in fiscal year 1985. An increase of $6,000,000 was adopted resulting in a total recommended authorization of $42,900,000. These activities provide the scientific support for the space flight missions that NASA conducts. This budget element supports early development work on instruments that will be flown

on missions and it supports the eventual analysis which turns data into information.

The Committee heard considerable testimony that this research infrastructure has not been adequately supported, especially in two areas—development work on new instruments and university research capital equipment. Accordingly, the increase would be apportioned as follows: $3,000,000 for laboratory equipment for universities to enhance their ability to conduct supporting basic research in the physics and astronomy program; and $3,000,000 to support advanced technology development on the advanced x-ray astronomy facility (AXAF) which was the highest priority mission recommended by the Astronomy Survey Committee of the National Academy of Sciences. The "Hearth Committee" study on NASA program management (a study requested by your Committee) found that NASA should fund more experimental and definition work early in a project's life in order to reduce technical, cost, and schedule risk when full development is underway. Based on this finding, which the Committee shares, more funding is needed for AXAF at this time. In addition, the Committee wants to signal its commitment to maintain a healthy astronomy program.

The Committee requests that within available funds NASA study the usefulness and feasibility of a shuttle-borne test of the Gravity Probe–B experiment.

*Shuttle/Spacelab payload development and mission management.* NASA requested $105,400,000 for Shuttle/Spacelab payload development and mission management activities in fiscal year 1985. These activities provide for development of experiments to go on the Shuttle, support the flights, and support the eventual data analyses. To date, a large fraction of the resources in this program has gone into the development of hardware such as pallets to mount experiments. The Committee urges that more emphasis be given to develop the scientific experiments to fly on the Shuttle, including (within available funds) smaller payloads which can serve university researchers. The Committee urges NASA to proceed with development of two larger payloads, the Solar Optical Telescope (SOT) and the Shuttle Infrared Telescope Facility (SIRTF). The Committee notes with concern that whereas these two projects were already approved when the Astronomy Survey Committee issued its 1982 report, nevertheless in fiscal year 1985 their full development is still not underway. This is particularly disturbing in the case of SIRTF which would be a fruitful follow-on to the Infrared Astronomical Satellite mission. The Committee further notes that SOT has been delayed largely because of development problems in the Space Telescope program, and hopes that this adverse interaction between the two programs is now past, and that SOT can proceed. Accordingly, the Committee added $4,000,000 for advanced technology development for SOT and SIRTF resulting in a total recommended authorization of $109,400,000 for Shuttle/Spacelab payload development and mission management for fiscal year 1985.

The Committee further urges that NASA give SOT favorable consideration if other programs can be accomplished at less than planned costs, thereby generating possible reprogramming opportunities.

## PLANETARY EXPLORATION

NASA requested $286,900,000 for planetary exploration activities in fiscal year 1985. The Committee increased funding for research and analysis by $10,000,000 making a total recommended authorization of $296,900,000 for fiscal year 1985.

*Research and Analysis.* NASA requested $54,500,000 for research and analysis activities for fiscal year 1985. The Committee added $10,000,000 resulting in a recommended total authorization of $64,500,000. The NASA Advisory Council study on the Mission of NASA found that NASA is "the only agency with the charter and skills" for planetary exploration, and that this should be a primary mission of the agency, if not "the overarching theme to guide . . . the agency for the years ahead." The Committee heard testimony to the effect that the request is too low to support a healthy program. NASA's own Solar System Exploration Committee also found the level of support too low in a study reported to the agency in 1983. Accordingly, the Committee has recommended that: $2,000,000 be added for laboratory equipment for universities to enhance their ability to conduct supporting basic research; and that $8,000,000 be added for supporting research and technology to support basic planetary research at universities. The fiscal year 1985 request for supporting research and technology is $37,900,000 while the 1981 level (in 1985 dollars) would be $49,300,000. Thus, while the increase would still leave the program below the 1981 level in purchasing power, it would move the program toward a more healthy level of support.

## SPACE APPLICATIONS

NASA requested $344,100,000 for space applications activities in fiscal year 1985. The Committee recommended that within available funding for solid earth observation/geodynamics activities $2,000,000 was authorized for measurement of crustal movements in the Caribbean Basin. Within Earth Observation activities the Committee recommended an increase of $5,000,000 for Space Physics Research and Analysis activities and a decrease of $5,000,000 in the Upper Atmospheric Research Satellite program. The Committee also recommended an increase of $40,000,000 for Communications activities. The total recommended authorization for space application activities in fiscal year 1985 is $384,100,000.

*Solid Earth Observations.* Within the funds available for Geodynamics activities, the Committee recommended an authorization of $2,000,000 to fund additional efforts on crustal dynamics. The Committee recognizes a need to make measurements of crustal movements in the Caribbean basin, a particularly active area, in order to better understand plate tectonics and improve methodology for earthquake predictions. These funds would permit completion of the acquisition of instrumentation and initiation of measurements in the field.

*Environmental Observations.* NASA requested $220,700,000 for environmental observations for fiscal year 1985. The Committee added $5,000,000 for space physics/research and analysis and reduced $5,000,000 from the Upper Atmosphere Research Satellite (UARS) mission for no net change.

The Space Physics/research and analysis increase is for advanced technology development for the International Solar Terrestrial Physics (ISTP) program, formerly called OPEN (Origin of Plasmas in the Earth's Neighborhood). This area of science potentially has important practical fallout because of its relationship to weather, climate, communications and other sun-related phenomena, and has been somewhat neglected by the agency. This is discussed more fully in Committee Views.

The Committee fully endorses the new initiative on the UARS mission and believes that the $5,000,000 reduction in the budget can be sustained with no significant affect on the UARS schedule. The Committee is aware that UARS experiments have been underway for some time, that they are relatively mature, and that spacecraft development must begin for most effective development. The Committee notes, however, that even after the reduction, $55,700,000 would remain in the budget for the mission and that the Agency would be free to strike the most appropriate and efficient balance between support of experiments and spacecraft.

The increase for ISTP advanced technical development activities when combined with the funds already in the budget request should serve to reduce the technical and schedule risk for this program. The Committee expresses again its interest in interdisciplinary research, and in Sun-Earth Interaction, and notes the complementary nature of the UARS and ISTP missions.

*Communications.* NASA requested $20,600,000 for communications activities including $5,000,000 for the restructure of the Advanced Communications Technology Satellite (ACTS) program by eliminating the flight portion while continuing the technology development and ground testing portion. The Committee disagrees with the restructuring and accordingly recommends an increase of $40,000,000 to continue the ACTS flight program as previously planned. The Committee recognizes that this amount is less than required for full funding of the flight program; nevertheless, the Committee directs NASA to proceed with the flight program and make the necessary future requests for budget authority as required. The Committee notes with concern the on-again, off-again agency posture with regard to flight demonstration of advanced satellite communications technology. Therefore, the Committee requests that NASA examine the question of recompetition at the outset to assure orderly and timely progress toward successful accomplishment of a flight demonstration program in concert with the user community. Therefore, the total recommended authorization for communications activities in fiscal year 1985 is $60,600,000.

## AERONAUTICAL RESEARCH AND TECHNOLOGY

NASA requested $342,400,000 for Aeronautical Research and Technology. This amount represents an increase of 13.3 percent over the Fiscal Year 1984 appropriation.

While this increase reflects substantial real growth from the previous year, the Committee notes that the long-term trend has not been adequate to keep pace with inflation, much less with the increasing sophistication of aeronautics. For example, the request for

FY 1985 is only 10 percent greater than the actual amount spent in FY 1980, without considering inflation.

The Committee notes that once again the Administration has failed to request funds to carry out Congressional intent in validating the Prop Fan technology. Accordingly, the Committee recommends that within the total authorization for Aeronautical R&D, $24,000,000 be authorized only for activities in the Advanced Turboprop program which are designed to lead to a flight test no later than 1987 and for supporting research and technology. This amount consists of $14,000,000 which is contained in the request under the Advanced Propulsion Systems Technology line item plus an augmentation of $10,000,000. Although the new authorization falls short of NASA's original request to the Administration, the Committee believes that essential program objectives can be achieved through a combination of cost reduction possibilities, including increased contractor cost sharing, greater in-house participation in flight test activities, and stretch out of non-time-critical supporting research. The Committee further recommends that NASA proceed with the parallel development of counter rotation technology so as not to let the promising new concept languish. Should further funds be needed NASA should reprogram from the R&D Base. The Committee wishes to reemphasize its intention that a flight test of the Prop Fan be performed in 1987.

The Committee is also concerned about a virtual abandonment, since 1981, by NASA of research focused on the disciplines related to high-speed aeronautics. Advances in this area will be the key to improved military and civil aircraft in the next century. Therefore, the Committee recommends an increase of $5,000,000 to be applied to research on variable cycle engine concepts, laminar flow, advanced materials and systems analyses.

The request contains $2,100,000 for research on alternative fuels for general aviation. To stress the importance of this work to the future of air transportation, the Committee recommends an increase of $1,000,000. The recommended authorization for Aeronautical R&D is $347,400,000.

To partially offset these increases, the Committee recommends a general reduction of $11,000,000 from the R&T base. Under Construction of Facilities, the Committee will recommend a further offsetting reduction to keep the total authorization for aeronautics at the level proposed by the Administration.

### SPACE RESEARCH AND TECHNOLOGY

NASA requested $150,000,000 for space research and technology activities in fiscal year 1985. The Committee recommended a $2,000,000 funding increase to support the tri-agency (NASA, DOE, and DARPA) SP-100 Program to develop a 100 kilowatt class space electric nuclear power system. The current funding level of $3,900,000 is inadequate to assure an orderly and efficient transition of this program into engineering development in FY 1986. The additional funds will be used to support a more thorough evaluation of the technological, safety, and mission related issues prior to concept selection for this program that may prove to be a valuable source of the high electrical power levels ultimately required by

manufacturing activities on the space station. The Committee recommends that the $2,000,000 increase in funding level be accommodated through a redistribution of available space research and technology funds resulting in a total authorization of $150,000,000 in fiscal year 1985.

## SPACE FLIGHT, CONTROL, AND DATA COMMUNICATIONS

### SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY

NASA requested $1,465,600,000 for Shuttle production and operational capability in fiscal year 1985. The Committee increased funding for the Orbiter by $50,000,000; decreased funding for launch and mission support by $15,00,000; and decreased funding for changes and system upgrading by $10,000,000 resulting in a total recommended authorization of $1,490,600,000 in fiscal year 1985.

*Orbiter.* NASA requested $606,800,000 for Orbiter production and related support in fiscal year 1985. The Committee recommends an increase of $50,000,000 for Orbiter funding to augment the structural spares activities (particularly critical skills needed for production and installation of electrical, mechanical, and fluid systems) and to avoid further erosion of the production base thereby maintaining production readiness for an additional orbiter vehicle. Therefore, the total recommended authorization for Orbiter activities in fiscal year 1985 is $656,800,000.

*Launch and mission support.* NASA requested $234,800,000 for launch and mission support activities in fiscal year 1985. Launch and mission support funding provides for a variety of improvements in such areas as mission preparation, mission operation, astronaut training, and launch and recovery operations. The Committee recommends a funding decrease of $15,000,000 which can be accomplished through the deferral of less critical activities that can be accommodated without a degradation of mission capability. This results in a total authorization of $219,800,000 in fiscal year 1985.

*Changes and system upgrading.* NASA requested $25,000,000 for changes and system upgrading in fiscal year 1985. These funds provide for potential changes and system modifications as well as unanticipated new requirements not covered in the budget estimates for Shuttle production and operational capability development. In view of the fact that Shuttle development is nearing completion, the Committee recommends a funding decrease of $10,000,000 resulting in a total authorization of $15,000,000 in fiscal year 1985.

### SPACE TRANSPORTATION OPERATIONS

NASA requested $1,339,000,000 for space transportation operations in fiscal year 1985. The Committee believes that increased operational efficiencies beyond those currently planned can be achieved and recommends a $10,000,000 funding decrease resulting in a total authorization of $1,329,000,000 in fiscal year 1985.

### SPACE AND GROUND NETWORK, COMMUNICATIONS AND DATA SYSTEMS

For fiscal year 1985, NASA requested $795,700,000 for space and ground network communications and data systems. The Committee

recommended a decrease of $15,000,000 resulting in a total recommended authorization of $780,700,000 for space and ground network, communications and data systems.

The recommended decrease of $15,000,000 would be applied at NASA's discretion within the line item. The Committee notes that the space tracking and data systems programs are oriented toward providing NASA with a general tracking, communications, and data processing capability. Thus, it is reasonable to expect funding reductions to be offset by improved operating efficiencies without a degradation in overall system capability and service. The Committee recognizes that NASA will be tempted to absorb the entire reduction through short-term, temporary curtailment in services. The Committee strongly urges NASA to avoid actions that degrade basic capabilities and jeopardize existing missions. In particular, NASA should not respond to this Committee budget action by taking steps that would delay or reduce efforts pertaining to development of the TDRSS or Deep Space Network or to acquisition and support of computational equipment (i.e., computers). Instead, the Committee directs NASA to pursue initiatives that will yield improved efficiencies and reduced funding requirements in the long term. Such actions may include, for example, initiatives to increase reimbursables, revised mission coverage policies, extend data processing turnaround time to coincide with a customer's ability to analyze data, curtail unnecessary communications traffic, and obtain greater funding contributions from other program offices for mission unique requirements.

## CONSTRUCTION OF FACILITIES

NASA requested $160,000,000 for the Construction of Facilities in fiscal year 1985. The Committee reduced the construction of the Numerical Aerodynamic Simulation Facility by $5,000,000 and reduced rehabilitation and modification of facilities at various locations by $5,000,000 resulting in a total recommended authorization of $150,000,000 in fiscal year 1985.

*Construction of Numerical Aerodynamics Simulation Facility.* NASA requested $16,500,000 in fiscal year 1985 for the construction of the Numerical Aerodynamic Simulation Facility at the Ames Research Center. The Committee reduced funding for this facility by $5,000,000 resulting in a total authorization of $11,500,000 in fiscal year 1985. The Committee expects NASA to reschedule the construction of the Numerical Aerodynamic Simulation Facility in a way which will facilitate the completion of this facility with fiscal year 1986 funds.

*Rehabilitation and modification of facilities at various locations.* NASA requested $25,000,000 in fiscal year 1985 for the rehabilitation and modification of facilities at various locations. The Committee continues to believe that it is essential that NASA maintain its property in a timely and economical manner. However, because of the restricted Federal budget for fiscal year 1985 and the urgent need to proceed with certain research activities in the space program, the Committee decided to reduce funding for the rehabilitation and modification of facilities at various locations by $5,000,000

resulting in a total authorization for these activities of $20,000,000 in fiscal year 1985.

## RESEARCH AND PROGRAM MANAGEMENT

NASA requsted $1,331,000,000 for Research and Program Management in fiscal year 1985. The Committee adopted the requested amount but directed that $1,000,000 be made available for the activities of the National Commission on Space, established pursuant to Title II of this bill.

## LANGUAGE AMENDMENTS

### SECTION 106

The Committee added a new Section 106 to clearly show the Committee's intent that NASA maintain production readiness for a fifth orbiter vehicle.

### SECTION 107

The Committee added a new Section 107 to direct NASA to continue and enhance the agency's programs of remote sensing research and development.

### SECTION 108

The Committee adopted a new Section 108 which expresses the intent of Congress that government expenditures in supporting the development of prop fan technology be repaid by firms in the aircraft manufacturing industry when and if commercially successful products employing that technology are produced by such firms.

The Committee is aware that cost recoupment has been a condition of certain research and technology contracts in the past where the objective was improvement of existing aircraft engines. In those instances the NASA research effort was expected to lead directly to specific product improvements and cost recoupment arrangments were relatively easy to design. While the "audit trail" from research to product is likely to be less apparent in the Prop Fan program, the Committee believes that any successful Prop Fan aircraft must draw heavily upon the current NASA research effort. For this reason, the concept of cost recoupment appears to be workable in this case.

Accordingly, the Committee recommends that NASA develop a plan for repayment of the Government's investment by firms in the aircraft manufacturing industry when a commercially successful Prop Fan aircraft is produced by any of those firms.

### SECTION 109

The Committee adopted a new Section 109, which would amend section 102 of the National Aeronautics and Space Act of 1958, as amended.

Sec. 109(a) would add a new subsection (c) to Sec. 102 of the National Aeronautics and Space Act, as amended, to require that the "National Aeronautics and Space Administration . . . seek and encourage, to the maximum extent possible, the fullest commercial use of space."

The Committee wishes to emphasize that this language is intended to encourage NASA to aggressively pursue all areas of potential commercialization.

The Committee commends the Executive Branch for its forward looking policies on the commercialization of space, which include the establishment of an office within the Department of Transportation for the commercialization of expendable launch vehicles. The Committee feels strongly that NASA, as the lead civilian space agency, should be encouraged to focus on commercialization opportunities. Toward this end, the Committee looks forward to the establishment of a focal point within NASA for space commercialization activities.

Sec. 109(b) would amend Sec. 102(d)(1) of the National Aeronautics and Space Act of 1958, as amended (and as redesignated by subsection (a) of Sec. 109), to reflect as an objective of the United States aeronautical and space activities "the expansion of human knowledge of the Earth and of phenomena in the atmosphere and space."

The addition of the words "of the Earth and" to the current language in the Act reflects the Committee's firm belief that research conducted in space, from space, or using space technology can greatly expand our understanding of the Earth and both natural and man-made process on it. The amendment is intended to encourage NASA's expanded activity in the Earth sciences.

### SECTION 110

NASA requested an amendment to Title III of the National Aeronautics and Space Act of 1958, as amended, to allow the NASA Administrator to transfer title to personal property loaned by NASA to academic institutions or non-profit organizations, once NASA is sure that it no longer needs the property. The Committee adopted a technical amendment to the language (Sec. 110).

### TITLE II

The Committee adopted a new Title II as amended to the bill which would establish a National Commission on Space whose purpose is to formulate a long-range agenda for United States civilian space activity, identifying long-range goals, opportunities and policy options for U.S. civilian space activity for the next 20 years.

The bipartisan Commission would be comprised of 14 Members selected by the President and the Administrator of the National Aeronautics and Space Administration. Other Federal Departments and agencies involved in civilian space policy, and Members of Congress would also be represented on the Commission in an ex officio capacity.

The Commission would report to the President and the Congress its findings and recommendations within a year following its establishment. The Commission would terminate 60 days following release of its findings and recommendations.

One million would be authorized under section 101(d) of Title I of this Act for the Commission's activities for fiscal year 1985.

# COMMITTEE VIEWS

## U.S. CIVILIAN SPACE POLICY

The next few years will be particularly important in establishing man's future in space. The placement in orbit of a permanent, manned space station will begin a new era, changing forever man's notion of space from someplace distant and unknown, to a place for scientific, economic and social gain. New technologies are enabling us to explore and utilize the space environment in altogether new ways.

These developments are reflected in the changing character of national and international space activity. Many more participants are entering the space arena, including government agencies, the private sector and foreign entities. Space commercialization activities are increasing and generating the need for new business and legal understandings and institutional arrangements. The Space Transportation System has emerged as a new national resource which vastly expands opportunities for space development. The evolution of space activities is also resulting in space policy considerations that command a presence in foreign policy. Tensions have also emerged from the growing perception of an increasing military involvement in space.

These changing trends translate into issues and policy considerations of increasing breadth and complexity. As policymakers, our ability to chart a course for U.S. civilian space activity will depend to a great extent on the presence of numerous conditions. Included among these are our ability to mobilize and utilize fully available scientific, engineering and technical resources, expertise and advice. The presence of an institutional organization and coordination that permits timely, informed and thorough debate and evaluation of, as well as an anticipatory responsiveness to, space policy considerations will be critical. Also essential will be the assurance of an open forum, particularly in the Executive Branch, in which civilian space policy considerations receive the priority and attention that are warranted.

During the next year, the committee intends to look in greater depth at the elements and character of the current institutional apparatus for setting space policy in order to ensure a foundation for more knowledgeable and confident decision making on U.S. space policy issues. In addition, the Committee will be examining the process by which decisions and policies are reached on civil space issues. In achieving these ends, the Committee invites the participation and advice of all parties interested in the future of U.S. civilian space activity.

## THE MISSION OF NASA

In the past, the Committee has voiced concern over the absence of long range goals to guide the U.S. civilian space program, and has encouraged NASA to enhance its long range planning efforts in order that a program direction for civilian space activity can be charted by the nation with greater confidence and commitment. It was with special interest, then, that the Committee received, in October of 1983, the report of the NASA Advisory Council on the Study of the Mission of NASA. The one and a half year long study on the long range missions of NASA, including science, exploration, technology, applications, and operations recommended a future course and direction for the agency over the next 20–40 years. The Council's report was a complement to hearings conducted by the Committee in October 1983 that reviewed the adequacy of the National Aeronautics and Space Act of 1958 as a policy framework for the next quarter century.

The Committee commends the NASA Advisory Council for initiating this exercise of such scope and introspection. The findings of the Council will provide useful reference and valuable insights as discussions of NASA's responsibilities and the objectives of our civilian space program proceed over the next several years.

The Committee believes that NASA's thorough scrutiny of the NASA Advisory Council's Mission of NASA study would be worthwhile and particularly appropriate as the agency postures itself to meet civil space objectives over the next several decades. Since the release of the Council's report in October 1983, the Committee has on several occasions queried NASA on its reactions to specific aspects of the Council's recommendations. These discussions have occurred primarily during the course of hearings on the agency's fiscal year 1985 budget request. Consequently, the Committee has not been able to explore the recommendations with NASA in as much depth as may be warranted.

Therefore, NASA is requested to submit to the Committee by September 1, 1984, its formal response to the NASA Advisory Council's study on the Mission of NASA.

## SPACE STATION DEVELOPMENT

Continued strength of our Nation's civil space program is dependent on a broadly based growth in the scientific and technological capability of NASA in the years head. The advent of a Space Transportation System has enabled both launch and retrieval of payloads in space as well as extended the time available for manned operations in space. Even though further extension of the orbital duration of the Space Shuttle can be expected, efficient longer term manned operations (beyond 18–20 days) indicates a requirement for a habitable, low-earth orbit station. Although any single objective (commercial, scientific or international) may not justify such a facility, when such objectives are considered as a whole, the development of a manned space station capability appears justified on the basis that such a capability will be of long duration (in excess of 10 years), expandable (adapted to changing requirements) and accessible (useable by commercial, scientific and international interests). Given these conditions, the Committee

fully endorses the Administration's request for definition studies for the Space Station program.

The Committee commends NASA in its decision to establish a Space Station Task Force and the resulting significant preliminary planning already conducted. This planning, in the Committee's view, has led to an improved basis for establishing a space station development program. Certain aspects of the planning for the development program, however, are of concern to the Committee, based on the testimony of NASA and others. NASA has expressed a determination to conduct the system engineering and integration activity as an internal NASA effort and to co-locate the program management (Level "B") with a NASA center. The Committee does not wish to attempt to "manage-at-a-distance" the space station program but does want to be assured that fundamental aspects of space station management have been exhaustively examined by senior NASA management. To this end, the Committee requests that NASA submit to the Committee not later than December 15, 1984, the NASA Space Station development management plan and procurement strategies with a description of the alternatives available and the basis for the choices taken. This management plan should include the approach planned for contracting, test-bed philosophy and facility planning, and other salient management considerations. The Committee believes that through development of this plan, the NASA and the Committee can better focus on management issues which may need further attention at the outset of the space station development program.

### SPACE SHUTTLE ORBITER

In the past year, the Space Shuttle has continued to prove its reliability, flexibility, and efficiency in serving as the Nation's primary space transportation system. However, a number of key policy issues relating to the Orbiter remain unresolved. NASA should continue to play an active role in addressing and resolving these issues in an expeditious manner.

*Orbiter Fleet Size.* The Committee continues to believe that an additional Orbiter beyond the currently planned four will be needed to accomplish civil, commercial, and defense missions and space station-related activities; to exploit the Shuttle's potential for extended on-orbit life, and to provide adequate backup to the currently planned fleet.

*Extended Duration Orbiter.* Spacelab users have emphasized that an extended on-orbit capability by the Orbiter would be very beneficial for their research efforts. An additional advantage of an extended duration Orbiter would be its ability to readily enter and use orbital inclinations that are different from the single inclination that will be occupied by the space station. Also, the cost of developing this extended on-orbit capability is of the same magnitude as the cost of a single Space Shuttle flight. The Committee believes that there is significant justification for developing an extended duration capability for the Orbiter and requests that NASA provide the Committee by September 1, 1984, a report on the costs and technical aspects of undertaking the development of an extended duration Orbiter. This report should address the following: (1)

NASA's recommendation of how the extended on-orbit capability of the Orbiter can best be accomplished; (2) the cost and schedule that would be required to implement the recommended technique; (3) identification of potential missions that would use the capability; and (4) NASA's views of whether an effort to extend the Orbiter's flight duration should be pursued or foregone.

*Other Orbiter Improvements.* A number of modifications have been suggested for the Orbiter to improve its performance, reliability, or cost efficiency. These have included potential improvements in the main engines, landing gear, brakes, wings, auxiliary power units (APU's), and thermal protection system. The Committee requests that NASA provide the Committee by September 1, 1984, a prioritized list of the improvements that are underway or are being considered for implementation along with estimates of their R&D and production/retrofitting costs and schedules.

*Spares and Logistics.* The Committee applauds the initiatives that have been taken by NASA to augment the spares budget in an effort to ensure the availability of an adequate supply of repair and replacement parts. The Committee is also pleased with NASA's efforts to ensure that those parts are purchased at a fair and reasonable price. Outstanding issues include: (1) the size and professional background of the staff required to oversee the Orbiter logistics program; (2) when all STS logistics oversight will shift to a single NASA field center; and (3) where depot-level maintenance will be conducted on the Orbiter. The Committee requests that it be kept informed of NASA's progress in resolving these issues.

### FENCED SHUTTLE OPERATIONS

In October 1983, the NASA Advisory Council recommended that the operating budgets, facilities, and personnel required to support an operational Space Shuttle be "fenced" from the rest of NASA's programs. The Council argued that such an action would: speed the transition to more efficient operations; help reduce costs; and ease the transfer of STS operations to the private sector or some new government operating agency, should such a transfer be desired. At issue is the rate at which this fencing effort should be undertaken—some government officials and outside experts believe that it should be undertaken soon while others feel that it should not be done until the late 1980s or early 1990s.

The Committee endorses the view that Space Shuttle operations should ultimately be separated from the rest of NASA's activities and believes that this should be done at the most rapid rate that can be accommodated without causing harm to the program.

In light of the current divergence of views regarding the completion of fencing efforts, the Committee requests that NASA develop a preliminary timetable for the completion of activities to fence all of the shuttle's operating budgets, facilities, and personnel. This preliminary timetable should include a rationale for the timing of each milestone and should be submitted to the Committee by December 31, 1984.

### IMPACT OF GOVERNMENT USE OF EXPENDABLE LAUNCH VEHICLES ON THE SPACE SHUTTLE PROGRAM

When the decision was made to develop the Shuttle, the policy of the United States Government was to have the Shuttle replace government expendable launch vehicles and satisfy all the launch needs of the United States Government, commercial, and foreign users. This policy, however, appears to be changing as the Shuttle nears full operational status. In a June 14, 1982 letter to NASA, the Office of Management and Budget articulated a position that the Shuttle fleet should be sized to accommodate only the needs of the Federal Government and that an appropriate price to charge commercial and foreign customers for any excess Shuttle launch capacity would be the highest price at which sufficient users will be available to utilize excess capacity. More recently, the Department of Defense has initiated steps to acquire a launch capability in the form of expendable launch vehicles that is supplementary to the Shuttle.

In view of the initial Shuttle policy and the apparent subsequent changes thereto, the Committee believes it is appropriate to examine the long-range implications of these changes on the Space Shuttle program. The Committee, therefore, directs NASA to undertake a study on government purchase of commercial launch services and to submit its findings to the Committee by October 1, 1984. This report shall identify and assess the impact on the total United States space program and on the operations, cost, and utilization of the Shuttle resulting from government use of expendable launch vehicles.

### SELECTION OF SUPPORT PLATFORMS FOR PAYLOADS

Expanded utilization of space and a proliferation in the number and kinds of payloads placed into space are inevitable future events made possible by the development of the Shuttle and various space technologies. The purpose and requirements of these payloads will differ widely and dictate the support configuration offering the greatest suitability and return-on-investment. Payloads may be placed on and supported by a freeflyer (i.e., a dedicated bus), an unmanned platform (i.e., a shared bus), the Space Station, or the Shuttle's Spacelab. Efficient and effective utilization of space resources depends on a proper matching between a payload and support platform.

To ensure the best use of space resources, the Committee believes that it is necessary to establish guidelines for determining when it makes sense to put payloads on either a freeflyer, unmanned platform, the Space Station, or Spacelab. The Committee, therefore, directs NASA to develop selection criteria for each available support platform to better serve the payload community. These guidelines should be submitted to the Committee by January 1, 1985.

### SPACE SCIENCE

*Health of the Space Sciences Program.* The Committee has received much testimony over the past year which has expressed concern for the health of the space sciences program. Although there

is a degree of balance in the space science program in the fiscal year 1985 budget request and no major ongoing initiatives are threatened with demise, this reflects stability at a low-level of support rather than the growth deemed necessary to have a truly vigorous space science program. The Committee believes that there is a need to increase support for basic research at universities and to develop new missions that expand our capabilities in order to maintain our world leadership position.

It is particularly important to preserve a commitment to achieve a healthy science program in view of the future resources that may be necessary for the development of the Space Station proposed in the fiscal year 1985 budget. The start of any major new engineering program generates a concern because of its potential for diverting resources from other programs including science-based programs, as developmental problems arise.

*Astronomy.* In 1982 the National Academy of Sciences published a report entitled, "Astronomy and Astrophysics for the 1980's" popularly referred to as the Field Study after its leader, professor George Field. This report, based on a consensus of the United States astronomical community, is of great value in laying out a blueprint for astronomy and astrophysics for the coming decade. The recommendations in this report deserve serious and prompt attention by NASA with a view towards implementation. Indeed, the Committee believes that NASA should have very good, explicit, and sound reasons for any deviation from the plan laid out in the Field Study.

The Committee notes that the Field Study endorsed two major projects which were assumed to be firm commitments. That is, these projects were taken as already approved, and the study focussed on the follow-on projects. These two major projects were the Shuttle Infrared Telescope Facility (SIRTF) and the Solar Optical Telescope (SOT). It is of concern, however, that neither of these programs are progressing at a satisfactory rate towards the dates originally projected. Cost overruns in other programs such as the Space Telescope have impacted the resources available for concept definition and preliminary studies.

Another major emphasis of the Field Study was the need to strengthen the infrastructure of the astronomy and astrophysical sciences. Vigorous basic research programs at United States universities are essential for training future scientists and engineers and ultimately, for dissemination of the latest scientific results to university students and the general public. Grants awarded through NASA's Research and Analysis program provide a direct stimulus to the academic community and are the mainstay for the infrastructure in the astronomical and astrophysical sciences. The Committee believes that NASA should reexamine its need to maintain the scientific infrastructure in this area.

In examining NASA's proposal to initiate the construction of a permanent manned Space Station, the Committee has recognized that this may have far-reaching implications for many other NASA program areas. The Committee believes that the conclusions of the Field Study may need to be reexamined by NASA and the astronomy community in view of the capabilities that the Space Station may offer. It is evident that missions previously planned for Shut-

tle or unmanned platforms may achieve different long-term utility if designed with the Space Station in mind.

The Committee directs that NASA undertake a review of current and future planned astronomical missions and assess the cost, schedule, engineering and scientific implications of evolutionary designs which may lead to installation on the Space Station. This study should be done in conjunction with a group analogous to the Astronomy Survey Committee of the National Academy of Sciences and should be reported to Congress by May 1, 1985.

*Space Telescope.* The Committee continues to be concerned over the progress toward completion of the Hubble Space Telescope. Although there are no "show stoppers" that can be identified, at present, the Committee believes that the schedule and cost risks associated with the remaining tasks are inappropriately high for a project of this magnitude and maturity and do not reflect well on program management. The fairly rigid schedule for the systems integration phase may inhibit the engineering quality control that the major investment in this project merits.

The Committee recognizes the management and organizational difficulties presented by the recommendations of the National Academy of Sciences report on Institutional Arrangements for the Space Telescope (the "Hornig" report). Notwithstanding these difficulties the Committee intends that NASA maintain its commitments to carrying out the spirit of the Hornig report in establishing and maintaining a dedicated Science Institute. This report clearly points out that the science data management system and ground control operations related to science should be at the Science Institute so they can be responsive to the needs of the science community. It seems that the complete scope of responsibilities of the Science Institute is only now being adequately defined because of earlier deficiencies in overall project definition and planning for the Space Telescope project. Delays and revisions in the Science Operations Ground System may be attributable, in part, to the difficulties NASA has had in sharing responsibilities with an external organization such as the Science Institute. The Committee urges NASA to reaffirm its commitment to the Science Institute and to provide to it the support necessary for the Institute to fulfill its role. The Committee points out that the true measure of accomplishment for the Space Telescope will be neither its fabrication nor orbital operation but the scientific progress that it will stimulate and that will be achieved for the most part by the external astronomy community. NASA should avoid the temptation to be "penny wise and pound foolish" in withholding the small amount of organizational and resource support to the Science Institute that would be necessary to fully develop the vision of the National Academy report. Perhaps more importantly the agency should give the Science Institute the kind of institutional breathing room necessary to allow a very dynamic program.

*Planetary Exploration.* Planetary Exploration constitutes a mission of NASA which is not shared with any other agency. Over the past two decades under NASA's leadership there have been over 40 encounters with planets and satellites by unmanned spacecraft. Through the exploration of other planets we have begun to better understand our own planet, Earth, and our place in the universe.

Each successive mission has in some way, added to our knowledge of fundamental planetary processes which have shaped our own land masses, our oceans and atmosphere.

The increased austerity of the NASA budget has, however, necessitated a new examination of our intellectual objectives and the need for an affordable approach to planetary exploration. It is crucial to capitalize on our 20-year investment and continue a robust and scientifically dynamic program with more modest outlays. In 1983 the Solar System Exploration Committee of the NASA Advisory Council completed a strategy report which provides a sound basis for structuring such a program. This strategy emphasizes mission continuity in a core program and low-cost innovative approaches to implementation of this core program.

The Committee urges NASA to adopt and strongly implement this core program or to explain clearly reasons for any deviation. The core program recommended supports the minimum level of continuity that will enable progress toward our major scientific objectives and retain the U.S. leading position in solar system exploration. One element of this strategy, the Planetary Observer series, constitutes a program of low-cost, modestly scaled missions using technology already developed for Earth orbital spacecraft. The Committee notes that the first of these, the Mars Geoscience/Climatology Orbiter (MG/CO) has been proposed as a new start in fiscal year 1985. The SSEC has emphasized, however, that the Planetary Observers should be a level-of-effort program that will require a commitment to follow-on missions after MG/CO. The success of this strategy will depend in large part on NASA's ability to constrain costs by maximizing the hardware and software inheritance, controlling the scientific mission scope, and minimizing changes after mission definition. Only in this way will the mission costs be controllable so that the Planetary observer program can be conducted like the Explorer program.

Although the core program represents the lowest level of support necessary for a healthy program base, NASA's goals should include the expanded scope outlined by the SSEC. One ongoing effort within NASA that may significantly contribute to future programs is the Research and Technology for Solar System Exploration Missions study reported to the Committee in January 1984. This effort examines the generic technologies needed for the low cost improvement of derivative spacecraft systems for the inner planet exploration mission, the Mariner Mark II systems for the outer planetary programs, and the advanced technologies for the larger scope missions. The Committee directs that NASA continue to pursue these technology developments in close coordination with the Solar System Exploration Committee of the NASA Advisory Council.

*University Support.* A common need in both the Physics and Astronomy program and the Planetary Exploration program is the infrastructure provided by the academic community. As noted above this community is both the training ground of the future and a constant source of intellectual stimulus that has proven to be a major strength of the U.S space science program. The university environment has fostered cross-fertilization of ideas between traditional disciplines which has resulted in abundant rewards. Although NASA does not have a direct mission to support academic

institutions, the return on investments made in universities are clear and of long-lasting benefit.

The Committee believes the recommendations of the NASA University Relations Study Group (which pointed out the need for equipment grants, augmented budgets for data analysis, and NASA-sponsored graduate student study programs) are of great value and should be implemented by NASA. The Research and Analysis budgets within the Astronomy and Astrophysics and Planetary Exploration programs provide direct support for universities. The Committee has taken actions in the fiscal year 1985 authorization to augment the Research and Analysis budgets in both programs by amounts somewhat less than responsive to the recommended needs but as much as could be found in this year of restraint.

NASA should take steps to ensure that the spirit of these recommendations are fulfilled by encouraging the acquisition of capital equipment of broad utility and fostering close relations between NASA centers and universities that will improve the access of university researchers to NASA equipment and facilities. NASA would also benefit from the cross fertilization resulting from such improved relations.

Another concern related to the health of the university space sciences is the failure of the Space Shuttle to offer low-cost and easily achieved access to space for individual experiments. The Committee has maintained an interest in programs such as Spartan and the Getaway Specials which could remedy this situation. In so far as there is demand for them they should be given a higher priority by NASA and implemented at a faster pace without development of additional large hardware items. The Committee believes that such efforts to diversify the opportunities to accomplish small-scale experiments in space will have scientific benefits and will stimulate the health of university space sciences.

*International Cooperation in Space Science.* The Committee believes that the goals of maintaining U.S. preeminence in the space sciences and fostering international cooperation are compatible and should be pursued with vigor. NASA must retain strength in all major areas but at the same time recognize the potential contributions of other nations in achieving mutually desirable goals. In particular, it must be noted that support of a vigorous university-based research program in the United States is a very inexpensive way of maintaining strength and flexibility so that we can react to and capitalize on foreign advances. It also puts the Nation in a better position to bargain for cooperative opportunities to fly instruments on foreign missions.

One example of such cooperation is the International Solar Terrestrial Physics program in which the United States, Japan, and the European Space Agency are contributing different satellite platforms to collect data on Sun-Earth interaction in a complementary way.

Another approach which should be explored by NASA is the concept of coordinating missions whose objectives are complementary. For example, a follow-on mission by the European Space Agency or Japan to continue mapping the infrared sources in the universe would greatly augment the data base collected by IRAS. This is not

to condone the slow development of SIRTF, but to recognize it and try to minimize its impact, and perhaps keep the United States researchers involved and supplied with data by getting an instrument aboard European or Japanese missions. This approach might be applied to many other astronomy missions to maintain a flow of data and support continuity in data analysis programs which would improve the long-term stability of the space sciences.

The Committee believes that in any international cooperative effort, NASA should achieve some degree of overall reciprocity. For example, the European Space Agency instrument carried aboard the Space Telescope might be complemented by a United States instrument aboard some European Space Agency platform such as ISO.

*Program Balance.* The major resource commitments that will be necessary in order to develop and construct a permanent manned Space Station have raised the concerns of many in the scientific community for the maintenance of a balanced program in the space sciences. This concern arises from a perception of the Shuttle development history. The Committee echoes this concern and will continue to examine the relative priority given to the space sciences to assure a vital and healthy program.

As NASA begins its transition into the Space Station era several considerations are of importance. Neither the Space Station nor the Space Transportation System must be allowed to divert resources from the space sciences. There must be available resources in which new starts can be accommodated through the developmental phase of the Station.

There is also a need to begin integrating the space sciences into the Space Station and its design as it evolves. The lessons learned from the Space Shuttle are of great relevance. Notwithstanding the original intention to design the Shuttle with science as a user, NASA did not maintain in place an institutional or organizational arrangement to ensure that this intention was carried through the protracted development period. Although NASA has established a useful task force structure to focus the views of the science community for the Space Station planners, the Committee is not satisfied that this constitutes an adequate institutional arrangement. For example, this body is advisory only, and advises the Associate Administrator for Space Science and Applications who will have relatively little control over Station development. The Committee considers the establishment of a permanent organizational framework to be necessary to fully integrate the needs of science into other engineering, economic and human factor considerations for the Space Station design and development.

Antecedent to this, and of equal importance, is that the space sciences should not be forced onto any specific platform which is not appropriate. The Committee recognizes that many missions will not benefit from the characteristics of the Space Station or the Space Shuttle and can achieve a greater effectiveness and increased scientific return on some other platform. All missions should receive equitable priority based on their scientific merits and should not be penalized because of any inherent incompatibility with elements of the Space Transportation System.

The Committee also emphasizes the necessity of maintaining balance within the space sciences between new missions and ongoing support of data analysis though the Research and Analysis budgets. Often the scientific community itself, in its desire for new missions, is responsible for the diversion of resources away from the Research and Analysis program elements. This results in a weakening of the university based infrastructure largely supported by these resources.

*New Missions.* At the time of its recent review of the NASA Five Year Plan, the Committee was given assurances that a sufficient number of new missions could be accommodated within the projected 5 year budget to maintain continuity and dynamic growth in all the space sciences. This requires that adequate resources be committed to project definition phases in order "the new start" schedules can be met with reliability. These project definition phases are contained in the Supporting Research and Technology and Advanced Technology Development programs within the major disciplinary programs.

The Committee is concerned that the resources available for such work may be so small as to lead to inappropriate competition among the new mission concepts. It is essential to maintain a balance among priorities both on the basis of scientific merit and according to project maturity.

Gravity Probe-B is, by any measure, a project with a potential for profound scientific return. The Committee has voiced support for this project and believes that it should be given serious consideration by NASA. The recent discussion of a Shuttle-based demonstration phase should lead to a full technical evaluation of this possibility.

The Committee would like to comment on Gravity Probe-B as a representative of a class of missions characterized by high risk with potential for great, fundamental scientific payoffs. Such missions should always be a part of NASA's goals and consciousness.

In its support for the Planetary Observer program, the Committee does not intend to signal that it feels these missions alone are enough for a vigorous exploration of the solar system. The Observers would be a *core* program with additional, much more ambitious missions. Specifically, as recommended by the Solar System Exploration Committee, NASA should develop the Mariner Mark II spacecraft. The purpose of a low-cost core program is to maintain balance and vigor in the space sciences in the intervals between the necessarily less frequent but much more ambitious missions that will be funded as resources are available. Thus, the Committee wishes to emphasize that new missions should form the expanded goals of NASA and will ultimately be the basis for quantum increases in our understanding of the processes which have shaped our universe.

## SPACE APPLICATIONS

*The Mission of NASA in Applications.* The Committee is cognizant of the fact that NASA has not yet satisfactorily defined its role in space applications. The trend towards commercialization of space, together with an overall redefining of the Federal role in re-

search and development, raises questions about the traditional scope of the NASA mission.

The Committee is also concerned that NASA's organizational approach to applications involves fundamentally dissimilar elements which may have further confused its role. That is, the application of basic science to broader uses (such as weather research) is very different from activities which seek to apply or demonstrate NASA technologies with direct commercial implications (such as the Advanced Communications Technology Satellite, or ACTS, program). The danger exists that the latter might receive a disproportionate emphasis due to a clearer short-term economic value, or that the former might be pressed inappropriately to demonstrate an economic value that would be hard to prove.

*Technology Demonstration.* The emerging interest of the private sector in investing in space systems and applications suggests that NASA's mandate to provide for the widest practicable dissemination of its technologies must be viewed very flexibly. Although a duplication of the private sector's capabilities is clearly inappropriate, the need remains to undertake a level of "follow through" activities that will ensure a smooth and efficient transition to the private sector. This necessitates some degree of overlap in which NASA and the private sector work in coordination in order to ensure that NASA's role can be successfully ended without loss of the potential benefits. The Committee notes that NASA has established an Office of Commercialization in order to be responsive to this need. The Committee believes that there should be close coordination between this Office and the Applications program. Of course, in pursuing commercialization of space technologies, NASA must avoid competing with private sector efforts.

Recently, the NASA decision to reduce the scope of the ACTS program to exclude a flight demonstration has raised concern over the ability to effect a smooth transition of these valuable NASA-developed technologies to the private sector. The ACTS program is an innovative approach toward expanding communications capacity and conserving the communications frequency spectrum. Without a flight demonstration, however, neither industry nor the potential users may be willing to take on the risks inherent in establishing a commercial operational system. The Committee believes that the benefits to society which would result from the implementation of these technologies merit the restoration of a flight demonstration program. Accordingly, the Committee has taken action to maintain the scope of ACTS to include such a flight demonstration.

NASA's continuing vacillation in the area of satellite communications probably exemplifies the worst possible situation in which industry is not supported by promised technical results, but is led to invest in proposals for NASA-sponsored work that may not materialize. The Committee is of course aware that the Agency is to some extent at the mercy of events beyond its control. Nevertheless, the Committee is also aware of the Agency's ability to influence events. With respect to satellite communications, the agency should take steps to create a situation which will not generate turnarounds such as almost occurred with ACTS. It is of utmost importance that NASA take full account of this when procuring sup-

port from the private sector in collaborative communications demonstration projects.

The Committee is also concerned that in some other applications areas NASA has failed to develop an adequate science base before undertaking expensive demonstration programs. There is not an easily identifiable program continuity to support many demonstration projects. NASA should examine its approach to technology demonstrations in order to place such efforts in an overall context consistent with its mission. A comprehensive plan is needed whereby each demonstration project would have well-defined objectives—that is a beginning, a middle, and an ending that would be a turnover to the private sector, operation by another agency (e.g., NOAA operating weather satellites) or another understanding of where the demonstration project should lead. Projects should be planned to accomplish some well-defined objective. Without such a plan NASA's role is confused, because it seems to be pushing technologies for their own sake, without connection to other values. The Committee notes the difference between applications and science programs—planetary exploration, for example, can be considered a value in itself.

*Applied Science.* One major element in NASA's application program which has received inadequate attention is related to the applied sciences. This is often interdisciplinary research and is a potentially fruitful source of technological progress. The Committee is cognizant of the fact that the benefits will be long-term rather than of immediate economic value. For example, NASA's weather research programs cannot be expected to solve all problems of weather prediction in any foreseeable timeframe, but the Committee should expect, even insist, that these programs continue to accrete knowledge and understanding. NASA should remain committed in these areas and should not associate low perceived commercial potential with low priority for these programs.

The Committee notes that two such program areas—microgravity science and information science—seem not to have received proper emphasis by NASA. The Agency should build strong scientific and technical programs in these areas, and let commercical applications and opportunities arise from the wellspring of knowledge developed. Indeed, if NASA develops a strong base, private industry may develop commercial applications on its own, as is being done with electrophoresis. Indeed, the potential for commercial application in these areas is so clear that the Committee urges the agency to be particularly careful not to inadvertently impede commercial activities. The Committee further urges NASA to augment the basic science in these areas and to assume a leadership role in advancing scientific progress.

### TECHNOLOGY UTILIZATION

Over the years, the Committee has maintained an active interest in NASA's commitment to provide the broadest practical dissemination and application of aerospace technology. In particular, the Committee has encouraged NASA to address the needs of small and minority firms located in rural, economically depressed areas. The establishment of NASA's Rural Applications Teams appears to

be responsive to this need. Within the funds authorized for Technology Utilization, the Committee directs NASA to continue operation of its Rural Applications Team. It is the intent of the Committee to promote national productivity, and to stimulate economic growth in all aspects of the private sector through the infusion of high technology applications.

### INTERDISCIPLINARY COOPERATIVE RESEARCH AND INFORMATION EXCHANGE IN EARTH SCIENCE

*Need for Interdisciplinary Cooperative Research.* The Committee recognizes the linkages that exist between the Earth, its atmosphere and oceans, the Sun, and the space plasma between the Earth and the Sun. Because of the interactive nature of the physical, chemical, and biological processes in these systems, an understanding of major ecological and environmental phenomena depends on full knowledge of the system interfaces. For example, the large uncertainties that exist in assessing the effect of rising carbon dioxide levels on global climate stem in large part from the unknown responses of the oceans and biological organisms to this change. Because much of science is based on breaking complex systems down into easily understood parts, traditional disciplinary research typically cannot develop an understanding of processes which take place at the interfaces between systems.

In addition to interdisciplinary research, there is also much to be gained from international cooperation. An earlier example of such research was the International Geophysical Year of 1957–58, during which thousands of scientists from over sixty nations participated in a dedicated geophysical research and observation program that yielded a wealth of data. This example is a valuable precedent, not only because of the knowledge gained, but also because it demonstrated that such efforts can transcend politics.

The Committee supports and endorses scientific initiatives that promote interdisciplinary and international cooperative research programs aimed at addressing significant global problems. Only through such programs can the necessary view of Earth as a system be obtained.

At the Unispace '82 conference in Vienna, the United States proposed a study called "Global Habitability," which would address the interaction between the atmosphere, biosphere, and oceans. This would reduce uncertainties which are common to many global environmental problems. The United States should fulfill this commitment by taking the lead in formulating a visible, coordinated program with an identifiable focus. Within the Federal Government, NASA should be very active, if not the leader, in formulating such a program.

Indeed, the Committee adopted an amendment to the National Aeronautics and Space Act of 1958 to add impetus to NASA's mission concerning the "expansion of human knowledge of the earth." This amendment to NASA's basic statutory direction is intended to formally reflect in NASA's charter the Committee's firm belief that research conducted in space, from space, or using space technology in one way or another can greatly expand our understanding of the Earth and both natural and man-made processes on it,

and that this expanded understanding can and will benefit all mankind.

*Solar-Terrestrial Research.* The Committee is concerned with the present state of intra-agency organization and support as well as interagency, and interdisciplinary cooperation for the study of Sun-Earth interactions. A greater degree of interaction in this regard would be of special importance in uniting different disciplinary groups such as solar physicists, space-plasma physicists, meteorologist, climatologists, atmospheric chemists, and others toward a common goal of increasing understanding.

In the legislative report accompanying the NASA FY 1984 authorization bill, the Committee directed that NASA initiate a study through the National Research Council of the scientific connections and importance of Sun-Earth interactions. The underlying objective of this study was to develop an overall plan for Federal research which would serve to coordinate the activities of NASA, NOAA, NSF, DOD, DOE, and USGS. Although each of these agencies have missions that properly have shaped their respective research programs, such a coordinated plan would enable a more structured approach which would most efficiently direct federal resources to those science areas in greatest need. The Committee is aware that NASA cannot direct its sister agencies, but hoped that NASA would lead by example and logical persuasion.

Notwithstanding the Committee's request, NASA has not assumed the leadership role envisioned. Perhaps the Committee's intent that NASA lead only by example and persuasion was not clear, or perhaps NASA has been focused on achieving better interdisciplinary coordination within its own activities rather than on the need for coordination of other federal efforts. Nevertheless, the Committee is not fully satisfied that the intent of the study requested last year will be achieved. The goals of interdisciplinary and international coordination should include interagency coordination.

*International Geosphere Biosphere Program.* The International Geosphere Biosphere Program (IGBP) recently described by the National Academy of Sciences, offers the opportunity to develop a higher level of cooperation between traditional scientific disciplines, between Federal Agencies having appropriate research mandates, and between other participating countries. Although based in concept on the International Geophysical Year, the IGBP recognized the need to extend the scope of effort to include Sun-Earth interactions as well as interrelationships between the lithosphere, biosphere, and atmosphere. IGBP will build on existing cooperative efforts such as the Middle Atmosphere Program, the Global Environmental Monitoring System, and World Climate Research Program, and many others to strengthen existing observation and monitoring systems.

For example, a coordinated observation and monitoring system would ensure that participants strive for the optimum scientific return from each system component. This would promote complementary measurements and avoid duplication of efforts.

The Committee notes, however, that at this time, the IGBP lacks a sufficiently crisp focus to achieve the stature needed. A substantial input and commitment by the science community and involved

Federal agencies is needed to achieve the degree of program definition desired if IGBP is to become a reality.

The Committee has examined NASA's research programs in Solid Earth Observations and Environmental Observations and concluded that these have the potential to make major contributions to IGBP. Missions such as the Upper Atmosphere Research Satellite and the anticipated International Solar Terrestrial Program could be the cornerstones to a successful IGBP. Resources spent by NASA in these areas might achieve greater results if coordinated within an overall international measurement and observation program.

The Committee urges NASA to support the IGBP in defining the scope and objectives and in developing future plans. The Committee anticipates that NASA will play a major role in evolving such future plans. NASA's active support of and participation in IGBP would go far toward meeting the Committee's desires for the study of Sun-Earth interactions described above. Over the next year, the IGBP will be defined in specific terms and its scientific goals will be formulated in preparation for its presentation to the International Council of Scientific Unions. The Committee looks with anticipation to the international acceptance of IGBP as a meaningful framework within which resources can be focused.

*Global Resource Information System.* The Committee has strongly encouraged the establishment of a global resources information system. The Committee considers such a system to be fundamental to the success of IGBP through facilitating information exchange. Data collected in both experimental and operational programs should be made available in a timely fashion and in a usable format to the scientific and technical community.

In the April 1981 Report on United States Civilian Space Policy, the Committee recommended that NASA develop a program plan for a Global Resource Information System (GRIS) utilizing an interactive network of relevant data bases. This sytem would be based on information needs of the world science community.

In February 1983, NASA responded with a plan outline which clearly emphasized computer hardware development rather than user needs or accessibility. In the FY 1984 Authorization Report, the Committee recommended an increased level of funding for the implementation of GRIS in the Space Applications Program in order to make clear that the focus should be on user-involvement applications rather than any new systems or hardware development.

Since this time, there has been little, if any, visible progress toward implementation of GRIS. The goal should be to assess user needs and to review existing data bases and information systems which may be better utilized. The scope should encompass not only systems and data bases developed by NASA, but also those of other relevant agencies. NASA should take the lead in developing such a system as a component of and support for IGBP.

*Report.* The Committee requests that, by May 1, 1985, NASA submit to Congress a report that reviews NASA's support and contributions to the IGBP, potential missions that can be coordinated through IGBP, and a data management plan that carries out the intent to improve accessibility to global resource information.

### HIGH-SPEED AERONAUTICAL RESEARCH

The Committee finds that NASA's aeronautical research efforts are generally applied to flight disciplines and categories in a manner consistent with the potential for future benefits. A notable exception is the area of high-speed aeronautics.

In the next century, the distinction between aircraft and spacecraft will become far less obvious than it is today. For example, it is possible to foresee the development of "aerospacecraft" that can operate both in the atmosphere and in space. Also, requirements for faster military aircraft, cruise missiles and civil transports are likely to emerge.

To prepare the technology base for these possibilities, NASA must expand its research in high-speed propulsion, aerodynamics, materials, structures and systems analysis. To begin this effort, the Committee requests that NASA prepare and submit, by November 30, 1984, a long-range technical and budget plan for a focused research program in these areas.

### ALTERNATIVE FUELS FOR GENERAL AVIATION

The price and availability of fuel continues to be a major barrier to the free expansion of general aviation. Since general aviation fuel represents less than one percent of the petroleum consumed in the United States, the production of general aviation fuels (80 grade avgas and 100 LL avgas) is the most severely impacted by fuel shortages. Forecasters now predict that one severe fuel disruption can be expected in the next five years, and that three such disruptions can be expected in any given ten-year period of time. Fuel shortages in the decade from 1972 to 1982 resulted in an increase in aviation fuel prices ranging from 600 to 1000 percent. Thus, fuel consumption has become an even more dominant factor in aviation economics.

The Committee has been particularly interested in the recent flight testing of a number of near-term alternative fuels for general aviation such as liquid methane, methanol, ethanol, gasohol, automobile gasoline and others. Independent test programs on many such alternative fuels have reached the point where their technical feasibility could be validated by research to determine the limits of detonation in high compression aircraft engines and the development of design parameters to permit the sound engineering of fuel supply systems for highly volatile fuel.

Therefore, the Committee requests that NASA prepare and submit to the Committee a technology readiness plan for alternative fuels for general aviation by December 31, 1984.

### STRENGTHENING INSTITUTIONS EDUCATING THE UNDERREPRESENTED IN SCIENCE AND ENGINEERING

The FY 1983 Annual Performance Report submitted by NASA in response to President Reagan's Executive Order 12320 to strengthen Historically Black Colleges and Universities indicates significant effort by NASA to develop a very effective program. The Committee is encouraged by the response of NASA. Testimony received by the Committee in the course of the FY 1985 authorization proc-

ess has clearly indicated, however, that other institutions serving significant numbers of black and other minority students have not evolved in the same way as have the historically black colleges. These other institutions tend to serve a diverse group of minorities and tend not to be the major research universities. In view of this finding, the Committee encourages NASA to look at those institutions of higher learning having significant minority enrollments in an effort to find ways to build closer relations with such schools, meet NASA's research objectives, and increase the number of individuals from underrepresented groups in the pool of graduate researchers. The Committee instructs NASA to develop a plan containing options by which it might build a closer relationship with institutions serving significant numbers of minorities while not diminishing its efforts toward the Historically Black Colleges and Universities. The Committee further instructs NASA to report this plan to the Committee not later than January 31, 1985.

### SOLID ROCKET PROPULSION TECHNOLOGY R&D

During the past year, a number of events occurred which demonstrated that some elements of solid rocket propulsion technology are still more of an art than an exact science. These events include: failure of an Inertial Upper Stage (IUS) nozzle during its second flight; unusually high erosion rates, and near failure, of the solid rocket booster nozzles during the flight of STS–8; failure of the rocket motor nozzles on each Payload Assist Module (PAM) used recently to launch the WESTAR VI and PALAPA B–2 communications satellites; and similar problems with MX upper stages. These events underscore the broad scope of the technological difficulties being faced by the solid rocket propulsion industry which jeopardizes a multitude of national interests. The Committee urges NASA to take a leadership role in identifying the causes of and solutions to the persistent solid rocket propulsion problems that have occurred recently. This may require that the agency pursue research efforts in the areas of basic materials characteristics, design models, manufacturing processes, and inspection and testing techniques. As a part of its annual budget process, NASA should report to the Committee its progress on these problems until they are resolved.

### INTERNATIONAL PARTICIPATION IN FINANCING OF ADDITIONAL ORBITERS

The Committee directs the Administrator to undertake an immediate study on the potential for international financial contributions toward the construction and operation of additional space shuttle orbiters. This study shall be completed and submitted to the Committees of the House of Representatives and the Senate with appropriate jurisdiction within 180 days of the enactment of this legislation and shall address the following:

The potential degree of financial support available from the international community;

Areas of appropriate international cooperation in the construction and operations of additional space shuttle orbiters; and,

Any other areas of NASA activities which could be supported, at least in part, through an international effort, thus making existing funding available for space shuttle orbiter procurement and operations.

## EXPLANATION OF THE BILL

### TITLE I

The bill authorizes Research and Development in section 101(a), Space Flight, Control and Data Communications in section 101(b), Construction of Facilities in section 101(c), and Research and Program Management in section 101(d). These activities are explained below:

## RESEARCH AND DEVELOPMENT

### SUMMARY

| | Authorization fiscal year 1985 | Page No. |
|---|---|---|
| 1. Space transportation capability development | $346,400,000 | 37 |
| 2. Space station | 150,000,000 | 48 |
| 3. Physics and astronomy | 687,200,000 | 51 |
| 4. Life sciences | 63,300,000 | 63 |
| 5. Planetary exploration | 296,900,000 | 68 |
| 6. Space applications | 384,100,000 | 76 |
| 7. Technology utilization | 9,500,000 | 102 |
| 8. Aeronautical research and technology | 347,400,000 | 105 |
| 9. Space research and technology | 150,000,000 | 134 |
| 10. Tracking and data advanced systems | 15,300,000 | 156 |
| Total | 2,450,100,000 | |

### 1. SPACE TRANSPORTATION CAPABILITY DEVELOPMENT, $346,400,000

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Spacelab | $69,300,000 |
| Upper stages | 92,400,000 |
| Engineering and technical base | 95,700,000 |
| Payload operations and support equipment | 56,300,000 |
| Advanced programs | 14,500,000 |
| Tethered satellite system | 18,200,000 |
| Total | 346,400,000 |

The principal areas of activity in Space Transportation Capability Development are efforts related to the Spacelab, the upper stages that place satellites in high altitude orbits, the engineering and technical base support at NASA centers, payload operations and support equipment, advanced programs study and evaluation efforts, and the development and first flight of the U.S./Italy tethered satellite system.

Spacelab is a major element of the Space Transportation System (STS) that provides a versatile, reusable laboratory which is flown to and from Earth orbit in the orbiter cargo bay. The first Spacelab launch occurred in November 1983. The program is being carried out jointly by NASA and the European Space Agency (ESA). NASA's support of the Spacelab development effort includes ancillary flight and ground hardware and system integration efforts which assure Spacelab compatibility with experiments and the orbiter leading to an operational capability.

The upper stages project includes the effort necessary to provide upper stages for use with the Space Shuttle to place payloads in orbits and trajectories beyond the capability of the Shuttle alone, primarily for planetary and geosynchronous missions. Current developments include the two-stage Inertial Upper Stage and the modification of the Centaur/STS for use in Shuttle. In addition, a new upper stage, the Transfer Orbital Stage, is being planned for use in launching the Mars Geoscience/Climatology Orbiter (MGCO) in 1990.

The engineering and technical base provides the core capability for the engineering, scientific and technical support required at the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), the White Sands Test Facility (WSTF), and the National Space Technology Laboratories (NSTL) for Space Transportation Systems research and development activities. In FY 1985 and subsequent years, computational capability is included to provide for complex flow dynamics modeling and other analyses in support of MSFC programs.

Payload operations and support equipment provides for developing and placing into operational status the ground and flight systems necessary to support the Space Transportation System payloads during prelaunch processing, on-orbit mission operations and, when appropriate, post-landing processing. Included within this program area are the Payload Operations Control Center, satellite servicing tools and techniques development, and multi-mission payload support equipment.

The advanced programs effort identifies potential future space programs and provides technical as well as programmatic data for their definition and evaluation. In support of this effort, advanced development activities are conducted to provide a basis for obtaining significant performance and reliability improvements and reducing future program risks and development costs through the effective use of new technology.

The Tethered Satellite System (TSS) will provide a new capability for conducting space experiments in regions remote from the Space Shuttle orbiter. The objectives of the initial TSS mission scheduled for late 1987, are twofold: (1) to verify the controlled deployment, operation, and retrieval of the Tethered Satellite, and (2)

to quantify the interaction between the satellite/tether and space plasma in the presence of a current drawn through the tether.

The initial Spacelab mission was launched on November 28, 1983, and was completely successful. During 1983 the pre-launch integration and checkout, launch and mission, and post-launch deintegration were successfully accomplished. Evaluation of mission data has begun. In addition, contracts for the procurement of initial spares for U.S.-sourced hardware were initiated. The planning for the procurement of operational spares and the establishment of a maintenance capability also continued during 1983. Staging activities for Spacelab-2 (SL–2), Spacelab-3 (SL–3), OSTA–3, and SL–D1 were started this year.

In upper stages, a joint development program with the DOD was initiated in FY 1983 for the use of the Centaur as an STS upper stage. The common vehicle, designated Centaur-G, accommodates a 40-foot long, approximately 10,000-pound payload in the orbiter vehicle bay, and is capable of placing it into geosynchronous orbit. A longer version of the Centaur-G, known as G Prime, is being developed for launch of the Galileo and International Solar Polar Mission (ISPM) spacecraft in mid-1986. The Centaur-G Prime vehicles are currently under procurement for the Galileo and ISPM missions. Procurement will be initiated in FY 1985 for two G vehicles to support the Venus Radar Mission (VRM) and TDRS–E missions.

The Payload Assist Module (PAM) program is to provide low cost transportation, principally for commercial spacecraft, from the Shuttle's low Earth orbit. The Delta class PAM–D is capable of injecting up to 2,750-pound payloads into geosynchronous transfer orbit. PAM–DII is being developed commercially and will be capable of placing a 4,100-pound payload into geosynchronous transfer orbit and will be available for launch by mid-1985. The Atlas-Centaur class (PAM–A) will be capable of inserting 4,400-pound payloads into the same orbit and will be system qualified by mid-1984. Eleven PAM–D's have been successfully launched atop the Delta expendable launch vehicle and five more were successfully flown on STS–5, STS–7, and STS–8.

The Transfer Orbital Stage (TOS) is a three-axis stabilized perigee stage that is being commercially developed by the Orbital Sciences Corporation (OSC) for use in the Shuttle. It will have the capability of placing 6,000 to 13,000 pounds in geosychronous transfer orbit and thus bridges the gap between PAM–DII and Centaur. The scheduled launch availability is late 1987. A TOS is planned to be used to launch the Mars Geoscience/Climatology Orbiter. NASA is monitoring the development of the TOS prior to acquiring flight hardware for the MGCO mission.

In payload operations and support equipment, payload integration support and payload-related hardware are developed and furnished for NASA payloads. A key activity currently underway is the support of the retrieval/repair mission for the Solar Maximum Mission spacecraft, which is being undertaken with funding supplied by both NASA and the Department of Defense (DOD). This mission in currently planned for mid-1984. Multi-mission payload equipment being developed includes a payload bay bridge structure to carry small payloads, apparatus for providing cooling of the heat generated in the orbiter bay by the radioisotope thermal gener-

ators (RTG's) used for planetary missions, and a standard mission cable wire harness for mixed cargoes.

The advanced programs effort, in addition to specific space station activities involving studies of station assembly and hardware commonality, will be focused on five major areas—satellite services, unmanned platforms, advanced transportation systems, crew systems, and generic space system capabilities. Satellite servicing systems will continue definition and advanced development work in remote and proximity operations. Continued efforts will be made in the areas of platform systems and servicing and advanced tether applications. Advanced transportation concepts will be studied including orbital transfer vehicles (OTV's), propellant management, advanced launch vehicles, and advanced STS analytical tools. Systems supporting human presence in space as well as generic work in space structures, orbital debris management and retrieval, and advanced avionics will be investigated.

The Tethered Satellite System (TSS) hardware development will begin in FY 1984 following the completion of an advanced development phase initiated in FY 1983. The Italians will also initiate hardware development in FY 1984 leading to a cooperative first flight in December 1987.

## SPACELAB

FISCAL YEAR 1985 FUNDING

| | |
|---|---|
| Development | $31,200,000 |
| Operations | 38,100,000 |
| Total | 69,300,000 |

The Spacelab is a versatile, reusable facility carried in the cargo bay of the Space Shuttle orbiter which affords scientists the opportunity to conduct scientific experiments in the unique environment of space. Ten European nations, including nine members of the European Space Agency (ESA), are participating in this joint development program with NASA. ESA has designed, developed, produced, and delivered the first Spacelab consisting of a pressurized module and unpressurized pallet segments, command and data management, environmental control, power distribution systems, and much of the ground support equipment and software for both flight and ground operations. The first unit of the Instrument Pointing System is scheduled to be delivered in FY 1984.

NASA is responsible for the remaining hardware including such major elements as the crew transfer tunnel, verification flight instrumentation, certain ground support equipment, and a training simulator. Support software and procedures development, testing, and training activities not provided by ESA which are required to demonstrate the operational capability of Spacelab are also included in NASA's funding. NASA is procuring an additional Spacelab unit from ESA under terms of the ESA/NASA Memorandum of Understanding and the Intergovernment Agreement.

Spacelab operations includes mission planning and flight and ground operations for all missions other than the development flights (SL–1 and SL–2). This includes integration of the flight

hardware and software, payload operations data management, and logistical support.

The major development efforts of the Spacelab program during 1983 have been the pre-flight, flight, and post-flight activities for the first Spacelab (SL–1) launched in November 1983. This mission carried a pressurized module and pallet configuration.

The Verification Flight Instrumentation (VFI) for SL–1 was delivered in March 1983. The Spacelab mission simulator became ready for training of the flight crew in April 1983 and numerous training simulations for SL–1 were held during 1983. In May 1983, the Payload Operations Control Center (POCC), used by the principle investigators to monitor real-time data and give commands to their experiments during flight, became operational and simulations were performed during the summer of 1983 in preparation for SL–1. The physical integration of the experiments to the Spacelab and of the Spacelab to the orbiter was completed during the summer of 1983. The first Spacelab launch occurred on November 28, 1983, and was completely successful. After the ten-day mission, data reduction was started and is still in progress.

The other major development activities during 1983 were the staging of Spacelab-2 (SL–2) pallets and the delivery from ESA of nine more experiment racks under the Follow-on-Procurement contract.

Operations funds in 1983 were required for the analytical integration and staging of some experiment racks for Spacelab-3 (SL–3) and the staging of the OSTA–3 pallet.

The first Spacelab operational flight (SL–3) is currently scheduled for the first quarter of FY 1985. FY 1985 funding is required to check out the Spacelab system components before flight and conduct post-flight data analysis for that mission. The second verification flight (SL–2) scheduled for the second quarter of FY 1985 will require funding prior to flight for physical integration, for checkout of the Spacelab elements, and for support of training including the operation of the Spacelab simulator. After the flight, SL–2 will require funding for deintegration of the Spacelab system components and for conducting post-flight data analysis. FY 1985 funding is required for the reflight of certain SL–1 instruments on the first Environmental Observation Mission (EOM–1) and for processing the first and second flights of the Materials Science Laboratory (MSL) and two Payloads of Opportunity Flights. The integration of the first life sciences mission (Spacelab-4) and astronomical observations mission (ASTRO–1) will also be in process this year. Analytical integration, configuration management, and software development for future flights will be conducted in FY 1985.

Procurement of spares for both NASA-developed hardware and for hardware developed by U.S. companies under contract with ESA will continue in FY 1985. Funds are also required to continue the expansion of the Software Development Facility to accommodate Instrument Pointing System software requirements necessary to support the planned flight rate. Production of the second Spacelab flight unit, which is under contract with ESA, will continue with all components scheduled to be delivered by the end of FY 1985. Funding is required for the initial lay-in and replenishment of spares for the ESA-delivered hardware, and for the establish-

ment and operation of depot maintenance for U.S.-provided and European-supplied hardware. The sustaining engineering for all hardware and software beyond ESA's commitment will also require funding in FY 1985.

### Upper Stages

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Development | $8,700,000 |
| Procurement and operations | 83,700,000 |
| Total | 92,400,000 |

The STS upper stages are required to deploy Shuttle-launched payloads to orbits not attainable by the Shuttle alone. The Inertial Upper Stages (IUS), the Centaur/STS, the Payload Assist Modules (PAM-A, PAM-D and PAM-DII—formerly the Spinning Solid Upper Stages (SSUS)), and the Transfer Orbit Stage (TOS) represent the four classes of upper stages that are or will be available for use with the STS.

The IUS was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit. The first IUS was successfully launched in October 1982 on a Titan 34-D booster. The first IUS/STS launch in April 1983 carried the TDRS-A spacecraft. The IUS failed to operate nominally during the second stage boost; the IUS anomalies are being resolved by joint USAF/NASA action. Four IUS vehicles have been procured for launch of the initial four Tracking and Data Relay Satellite System spacecraft; the first three were funded by the TDRSS contractor, while the fourth is funded under this budget element.

NASA and DOD have entered into a joint development program for a wide-body derivative of the Centaur stage as used in the Atlas-Centaur program. The common vehicle, designated Centaur-G, will accommodate a 40-foot long, approximately 10,000-pound payload in the orbiter vehicle bay, and be capable of placing it into geosynchronous orbit. A longer version of the Centaur-G, known as G Prime, is being developed for launch of the Galileo and ISPM spacecraft in mid-1986. Two Centaur-G Prime vehicles are currently under procurement for the Galileo and ISPM missions and procurement will be initiated in FY 1985 for two G vehicles to support the VRM and TDRS-E missions. The Air Force and NASA will equally share common design and development costs for the Centaur-G. The Air Force and NASA will separately budget for hardware production and operations costs associated with each agency's missions. Both NASA and DOD plan additional procurement of vehicles at a later date to meet future requirements. The planned activities for Centaur in 1985 include the work required on the RL-10 engine used in the Centaur stage, to provide added capability for NASA and DOD missions.

The objective of the Payload Assist Module (PAM) program is to provide low cost transportation, principally of commercial spacecraft from the Shuttle's low Earth orbit to geosynchronous transfer orbit. The Delta class PAM-D is capable of injecting up to 2,750-pound payloads into geosynchronous transfer orbit. The Atlas-Cen-

taur class (PAM–A) will be capable of inserting 4,400-pound payloads into the same orbit. PAM's are being developed commercially, but NASA monitors the development and production to assure that the PAM is technically adequate and will be available when needed. Eleven PAM–D's have been successfully launched atop the Delta expendable launch vehicle and five more were successfully flown, two each on STS–5 and STS–7 and one on STS–8. The PAM–DII is being developed commercially and will be capable of injecting 4,100-pound payloads into geosynchronous transfer orbit for missions beginning in early to mid-1985.

TOS is a three-axis stabilized perigee stage that is being commercially developed by the Orbital Sciences Corporation for use in the Shuttle. It will have the capability to place 6,000 to 13,000 pounds into geosynchronous transfer orbit, and thus bridge the gap between PAM–DII and Centaur. The scheduled launch availability is late 1987.

The FY 1985 development funds are required to complete the qualification testing on the Centaur-G Prime structural test vehicle and to complete the NASA share of the funding for the development activities associated with the Centaur-G and G Prime. Funds are also required to support development activities at KSC in preparation for Shuttle/Centaur launches. In addition, the RL–10 engine improvement program, used in the Centaur stage, will be continued in order to provide increased capability for NASA and DOD missions. Also, technical monitoring of the PAM–D, PAM–DII, and TOS upper stages will be continued.

Operations funds in FY 1985 are required to complete production and acceptance of the two Centaur-G Prime vehicles to support the Galileo and ISP launches in May 1986 and initiate production of two Centaur G vehicles to support the VRM mission (scheduled for launch in 1988) and the TDRS–E mission (initial launch capability in 1988). Operational funds are also required for KSC to process the pathfinder test vehicle and avionics simulator in preparation for the Galileo and ISPM flight vehicle processing. Funds are required to complete the procurement of NASA's one remaining IUS vehicle and to support IUS checkout and the stand-by launch capability for the ground spare spacecraft of the Tracking and Data Relay Satellite System (TDRS–D).

## Engineering and Technical Base

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Research and test support | $44,600,000 |
| Data systems and flight support | 17,000,000 |
| Operations support | 41,100,000 |
| Launch systems support | 3,000,000 |
| *General reduction* | *−10,000,000* |
| Total | 95,700,000 |

The engineering and technical base (ETB) will provide only the core capability required to sustain an engineering and development base for various STS programs. Additional center program support requirements above the core level are funded by the benefitting programs, such as Shuttle operations and Shuttle production and capability development. The centers involved are the Johnson

Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the National Space Technology Laboratories (NSTL).

The core level of support varies from center to center due to programmatic and institutional differences. At JSC, the core level requirement is that one shift of operations be maintained in the engineering and development laboratories, the White Sands Test Facility, and reliability and quality assurance areas. The core level for the Central Computer Complex is established as a two-shift operation. The funding for center operations base support is split between the ETB and Shuttle operations budget elements in accordance with the principle that ETB will provide the core level and the benefitting program is responsible for funding additional support requirments. At KSC, due to its operational character, the core levels provides for future studies and ground systems research and development. ETB funds at MSFC provide for multi-program support activities, including computational and communications services, and at NSTL for facilities operations, including security.

The requested funding for the ETB in FY 1985 provides for a continuation of the FY 1984 level of support for institutional research and development facilities and services at the centers. The increase in FY 1985 budget authority requirements over FY 1984 reflects the effects of inflation and an increase in computational capabilities at MSFC.

In research and test support, funding will provide increased computational capabilities at MSFC for engineering and science projects. Increased computational capabilities offered by acquisition of a class VI system are needed, for example, for the solution of more complex SSME three—dimensional dynamics modeling problems and for complex structural analyses. At JSC, this funding will provide a five-day, one-shift operation for the safety, reliability and quality assurance activities and for the engineering and development laboratories, such as the Shuttle Avionics Integration Laboratory (SAIL), the Electronic Systems Test Laboratory, and the Water Immersion Facility. Present supporting activities at MSFC will be continued during FY 1985.

Data systems and flight support provide a minimal core level of support based on a five-day, two-shift operation of the Central Computer Complex at JSC.

Operations support funding provides for the maintenance of technical facilities and equipment, chemical cleaning, engineering design, technical documentation and analysis, telecommunications, component fabrication, photographic support, and logistics support. Examples of specific services to be provided in FY 1985 include: (1) operation and maintenance of specialized electrical and cryogenic systems, and maintenance of test area cranes; (2) operation of shops to do metal refurbishing, anodizing, plating, stripping, and etching of selected items of in-house hardware; (3) engineering, installation, operation, and maintenance of closed circuit fixed and mobile television required for the support and surveillance of tests; (4) photographic services, including still and motion picture processing, and audio-visual mission support; (5) fabrication of models, breadboards, and selected items of flight hardware; (6) technical documentation services, telecommunications, and graphics; (7) tech-

nical services in support of center operations including receipt, storage, and issue of research and development supplies and equipment and transportation services; and (8) management services in support of center operations, including data management, microfilming, and preparation of technical documentation. In addition, FY 1985 funds will provide the basic level of institutional support at NSTL for continuing SSME testing activities.

In launch systems support, funds are required to continue investigations of the research and development technologies available to enhance launch site hardware, ground processing, and support systems.

### Payload and Operations Support Equipment

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Payload operations | $40,200,000 |
| Payload support equipment | 16,100,000 |
| Total | 56,300,000 |

The payload operations and support equipment objective is to centralize the provision of payload services, both unique and common, which are required beyond the basic standard Shuttle services. Payload operations provides unique hardware, analyses, and launch site services to support STS missions—including management of the Solar Maximum Mission retrieval/repair activities. Payload support equipment funds the development and acquisition of reusable ground support equipment required for a wide range of payloads including Spacelab. In addition, this program provides for the activation and operations through completion of development flights of the Payload Operations Control Center (POCC) located at JSC. This facility enables command and control of Shuttle/Spacelab attached payloads. The POCC performed exceptionally well in support of the first Spacelab mission launched on November 28, 1983.

Payload operations funding in FY 1985 is required to furnish continued payload services for currently scheduled NASA launches. Major payloads receiving support during this year include Galileo, VRM, ISPM, TDRS, Space Telescope, SL–2, and SL–3.

FY 1985 funding for payload support equipment will be used for the development, test, and installation of mixed cargo and test equipment, on-site cargo transporter, and long-lead initial spares. FY 1985 funding is required to maintain and operate the POCC, located at JSC, as well as support SL–3, SL–2, and minor missions. After SL–2, the maintenance and operation of the POCC will be funded out of the Spacelab operations budget.

### Advanced Programs

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Advanced programs | $14,500,000 |

The principal objectives of advanced programs are to conduct mission requirements analyses, conceptual system definition, detailed system definition, and advanced and supporting develop-

ments to acquire the technical and programmic data for the evaluation of new space flight initiatives. Future space program and systems requirements, configurations, costs, and capabilities are identified to provide the basis for development decisions on new space flight systems. Past program efforts have provided such information for new major agency programs and systems including Apollo, Skylab, and the Space Transportation System. Subsystem studies and advanced and supporting development are conducted to demonstrate the required performance and reliability. Improvements to reduce future system program cost and performance schedule risks will also be investigated.

In FY 1984, the advanced programs effort, in addition to specific space station activities involving studies of station assembly and hardware commonality, is focused on five major areas—satellite services, unmanned platforms, advanced transportation systems, crew systems, and generic space systems capabilities. Satellite servicing systems continue definition studies and advanced developments in satellite placement and retrieval; manned extravehicular activity (EVA) spacecraft and platform resupply, maintenance, and repair; rendezvous and proximity operations; satellite maintenance and repair in low and geostationary Earth orbit; and autonomous capabilities. In unmanned platforms, definition activities continue in free flying and tethered space platforms for low and geostationary orbits to operate from the Shuttle. Advanced transportation focuses on definitions of reusable orbital transfer vehicles (OTV), Shuttle-derived launch vehicle concepts, porpellant scavaging, space-based operations of OTV's and aft cargo carrier concepts. Crew systems efforts will focus on definition and advanced development of an advanced Shuttle EVA system, and preliminary definition of habitability systems for long duration space flight. Generic space system capabilities will include studies related to space debris and its management. Preliminary definition and ground simulation evaluations of assembly and construction operations for large space systems and orbital structures will be pursued leading to flight demonstration candidates for key validations of capability and to test bed evaluations of fault tolerant avionics subsystems. A major thrust in fiscal year 1984 is the detailed definition of alternative concept system studies of an Orbital Maneuvering Vehicle (OMV). The OMV will provide a new STS reusable extension capability for conducting orbital operations with spacecraft and payloads beyond the practical operational accessability limits of the baseline STS. By use of direct man-in-the-loop control, the OMV will operate as far as 800 to 1400 nautical miles from the orbiter for delivery, maneuverability, reboost and retrieval of satellite payloads, servicing of satellites and platforms and retrieval of space debris.

In FY 1985, major emphasis will be placed on system concept definition and key advanced developments in crew systems, low and geostationary Earth orbital unmanned platforms, reusable OTV's, new capability mission kits for orbital maneuvering vehicles, future tethered systems applications, satellite servicing systems near and remote from the orbiter, aft cargo carriers, and generic space systems capabilities. The overall goal continues to be

the definition of the systems architecture and space elements needed for space operations over the next twenty years.

A major effort is planned to define one or more unmanned launch vehicles drawing heavily on the STS hardware, launch facilities, and experience. It is anticipated that significantly reduced cost-per-pound and cost-per-unit volume can be achieved by this means, and larger, heavier payloads accommodated as well. Continued colaboration with DOD, which has identified similar needs, is planned.

In the crew systems area, the continued evaluation of water and air loop regenerative life support initial prototype subsystems will continue at the unmanned test level and definition and advanced development of improved EVA systems will be pursued. Increased emphasis on preliminary definition of OTV systems and Shuttle-derived launch vehicles will be accomplished in advanced transportation including a detail systems engineering understanding of space basing and what key advanced developments must be initiated. Unmanned platforms will focus on geostationary platforms capability definition and delineation of critical mechanisms and designs which require advanced development efforts. Under unmanned platforms, detailed engineering systems analysis will be continued to determine the efficiency of future tethered platforms applications. Satellite servicing systems will continue detail definition, prototype development, and ground-based developmental testing of high leverage manned servicing tools, equipments, interface hardware, and operational techniques for in-the-bay and near the orbiter spacecraft and platform servicing. Satellite servicing will explore remotely manned servicing to extend manned STS operational capability for remote low and geosynchronous Earth orbit support of spacecraft, platforms, and constellation aggregates. Generic space systems capability will continue to develop a fault tolerant avionics capability leading to a test bed evaluation, conduct definitions and simulations of construction and assembly of large space systems and structural elements establishing techniques and systems engineering understanding, and to pursue analysis and potential in situ verification of space debris and its control.

### Tethered Satellite System

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Tethered satellite system | $18,200,000 |

The development of a Tethered Satellite System (TSS) will provide a new facility for conducting space experiments at distances up to 100 kilometers from the Space Shuttle orbiter while being held in a fixed position relative to the orbiter. A number of significant scientific and engineering objectives can be uniquely undertaken with a TSS facility, such as: the observation of important atomspheric processes occurring within the lower thermosphere; new observations of crustal geomagnetic phenomena; and entirely new electrodynamic experiments interacting with the space plasma. This is being undertaken as a cooperative development program with the Italian government.

The United States TSS hardware development of the deployment mechanism began in FY 1984 following the completion of an ad-

vanced development phase initiated in FY 1983. The United States is also responsible for overall program management and orbiter integration. The Italians completed the definition phase in FY 1983 and plan to initiate the satellite hardware development in FY 1984. They are responsible for the satellite development and instrument and experiment integration. Formal signing by representatives of both governments of a memorandum of understanding is expected in the second quarter of FY 1984.

The FY 1985 funding will continue the hardware design and development through the preliminary design review leading to a critical design review early in FY 1986 and an engineering verification flight in December 1987. The planning estimate for the total development cost for the United States activities has increased to $50–60 million because of a recent project assessment of mission complexity in hardware and integration indicating a potentially higher cost for the TSS hardware development. Also, the funding for the payload-unique STS integration for the first flight has been included in the TSS budget this year for improved management control.

**2. SPACE STATION, $150,000,000**

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Utilization requirements | $14,100,000 |
| Supporting studies and program support | 12,200,000 |
| Focused technology | 34,200,000 |
| Advanced development | 20,200,000 |
| Flight experiments | 11,000,000 |
| Systems definition/integration | 58,300,000 |
| Total | 150,000,000 |

The United States space station will establish a permanent human presence in space to expand the exploration and use of space for activities which enhance the welfare and security of mankind. The program is built upon the operational capabilities of the Space Shuttle and represents the next logical step in U.S. space capability development. The program is responsive to the basic goals of the President's National Space Policy which calls for U.S. leadership in space and economic and scientific benefits through the exploration of space.

The United States space station will be a multi-purpose facility providing a permanent human presence in space to conduct essential scientific and technical research, to perform unique commercial activities, and to perform more efficiently operational tasks in space, such as satellite servicing, construction and servicing of platforms, placement of spacecraft into higher orbits. The space station will have both manned and unmanned elements and will involve extensive national and international user community participation in such areas as science, applications, manufacturing, communications, satellite servicing, and, potentially, national security. From the outset of the program definition effort, the space station itself will incorporate a modular design philosophy which will permit the system to evolve through time, to provide greater user utility through simplified user interfaces and improved capability for on-orbit crew maintenance and operational autonomy in order to achieve effective long-term performance. Implicit in these objectives is the recognized need to optimize the synergistic effects of

the man/machine combination in space via automation, robotics, and artificial intelligence technology. It will provide essential system elements and operational practices for an integrated national space capability. The space station facility (core and associated platforms) will be placed and maintained in low-Earth orbit by the space transportation system.

A basic premise of the space station program is to perform a thoroughly detailed front-end definition including: engineering design by industrial contractors; subsystem advanced development and tests in dedicated test beds; early flight experiments on the Space Shuttle to prove system feasibility; and continued trade studies for system optimization. Extensive engineering definition incorporated directly into hardware specifications provides the greatest single assurance of program success and the achievement of cost targets. Throughout the definition period, significant effort will be focused on growth potential and modular configurations to insure that the initial station will be capable of evolutionary growth in both size and technology. Following an extensive definition program, consisting of both in-house and contracted activities, development will begin in FY 1987 with orbital activities beginning in the early 1990's.

The program is currently conducting studies in the areas of mission requirements, user requirements, and architectural options. The Concept Development Group has conducted various system engineering and design trade-off studies. A number of configurations have been analyzed for engineering, operational and cost considerations. System requirements have been developed to provide guidance to contractors working on preliminary design. In addition, requirements have been developed by both the Mission Requirements and the Operations Working Groups. The Program Planning Working Group has conducted long-range planning and has evaluated several management and acquisition options. Preliminary planning has been conducted to lay the groundwork for establishing a source selection board in FY 1984 for the system definition contracts. In addition, the Space Station Technology Steering Committee has defined a technology program that integrates the generic technology, focused technology, advance development and flight experiments for the various subsystems such as power, electrical, data management, and crew and life support. The subsystems have been prioritized and schedules have been developed to provide a transition from the technology development to Phase C/D development.

Fiscal year 1985 funding will be used to support the following activities:

*Utilization Requirements.*—This activity develops functional and user operational requirements based on both national and international missions. These requirements specify customer needs in terms of power, volume, services, heat, communications, etc. Consideration is being given to interests such as on-board accommodation, servicing free-flying spacecraft already launched, constructing and servicing platforms, placement of spacecraft into various required orbits, and commercial endeavors in the field of life sciences, astrophysics, environmental sciences, materials processing, and advanced technology development.

*Supporting Studies and Program Support.*—Analysis of space station architecture and preliminary system and subsystem requirements are driven by and complement the ongoing and in-house trade study efforts in such areas as human productivity, satellite and orbital transfer vehicle servicing, structures and mechanisms, operations, auxiliary propulsion, maintainability of the systems, and thermal control systems definitions. Studies will be performed to define the space station requirements of elements in assembling the space station as well as servicing satellites and the necessary operations associated with these tasks. Also, planned studies will determine the feasibility and the potential cost savings achievable from space station hardware commonality. In addition, these funds are needed for the program information system, a combination of integrated software and compatible distrbuted hardware to enhance the distribution of pertinent data for effective program management and control.

*Focused Technology.*—This effort builds upon a generic technology base and focuses the technology development in those areas that will support space station development. The approach is to define requirements and timeliness for space station implemention, to develop options for space station application and to carry enhancing and enabling technologies into brassboard prototype programs, i.e., advanced development. The FY 1985 funding request is built upon the continuing FY 1984 generic technology efforts in the Space Research and Technology program which have identified several promising areas of technology including energy; dynamics and control; power, propulsion, and crew/life support; information and automation; operations; and enhanced human capabilities.

*Advanced Development.*—This program provides the "transfer" function between technology and system development. The approach is to select high leverage technologies from the focused technology program for brassboard/prototype demonstrations to evaulate technology alternatives, to quantify their respective performance and estimate their development risk from both cost and schedule standpoints. This test and demonstration activity will be conducted in test beds which will be developed along major subsystem disciplines. The initial technology test beds will be the following: environmental control/regenerative life support; electric power generation, storage, and distribution; thermal management; operating/data management; attitude control; on-board propulsion; and, space operations mechanisms. Examples of key technologies which are identified for the advanced development program are: solar concentrator arrays and regenerative fuel cells in the power area; a two-phase thermal bus for heat acquisition/transport and deployable heat pipes in the thermal area; carbon dioxide concentration/removal and water reclamation in the life support area; gaseous hydrogen/oxygen propulsion systems for orbit maintenance; and, docking/berthing systems in the space mechanisms area. Implicit in each of the test bed areas is the objective to develop and apply automation technology to optimize capabilities for fault detection and isolation, on-orbit repair and routine operation, and maximum user utility.

*Flight Experiments.*—The purpose of this activity is to use the unique space environment provided by the Space Shuttle to vali-

date the performance of critical components and subsystems which cannot be validated in ground tests in order to verify and quantify calculated performance, to identify unforeseen anomalies, and to update engineering design criteria. It will also demonstrate techniques, sensors, tools, and procedures required for space station control, maintenance, and repair and servicing operations. Candidate Space Shuttle flight experiments include environmental interaction plasma effects, contamination, cryogenic fluid management, thermal systems, and environment control life support system hardware.

*Systems Definition/Integration.*—This effort provides for the analysis and engineering design to define the various elements that will make up the space station. Conceptually, these elements consist of various modules such as the habitability, logistics, resource and laboratory modules, and the various subsystems such as power, propulsion, data management, communications, and environmental control/life support systems. This effort will be divided into a two to four work packages to be completed among industry in with contracts to be awarded in FY 1985. The definition contractors performing these Phase B efforts will conduct detailed definition studies and preliminary design, as well as hardware demonstration of critical items. The results of the focused technology, advanced development, and flight experiments will be incorporated into the definition studies being performed by the Phase B contractors. This early design phase will allow the selection of those design concepts that will provide the optimum mix of cost, schedule, and technical elements prior to initiation of full-scale development. This approach assures widespread industry involvement with competition for each work package. Current planning calls for two contractors to be selected for each work package for the Phase B effort. At the end of the Phase B effort, one contractor will be selected per work package to continue on with full-scale development. The integration of these various work packages will be performed by NASA in-house personnel utilizing some contractor support for system engineering.

### 3. PHYSICS AND ASTRONOMY, $687,200,000

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Space telescope development | $195,000,000 |
| Gamma ray observatory development | 120,200,000 |
| Shuttle/spacelab payload development and mission management | 109,400,000 |
| Explorer development | 51,900,000 |
| Mission operations and data analysis | 109,100,000 |
| Research and analysis | 42,900,000 |
| Suborbital program | 58,700,000 |
| Total | 687,200,000 |

The major objective of the Physics and Astronomy program is to increase our knowledge of the origin, evolution, structure, and composition of the universe, including the Sun, the stars, and other celestial bodies. Space-based research is being conducted to investigate the structure and dynamics of the Sun and its long- and short-term variations; cosmic ray, x-ray, ultraviolet, optical, infrared, and radio emissions from stars, interstellar gas and dust, pulsars, neutron stars, quasars, blackholes, and other celestial sources; and the

laws governing the interactions and processes occurring in the universe. Many of the phenomena being investigated are not detectable from ground-based observatories because of the obscurring or distorting effects of the Earth's atmosphere.

To achieve the objectives of the Physics and Astronomy program, NASA employs theoretical and laboratory research; aircraft, balloon and sounding rocket flights; Shuttle/Spacelab flights; and free-flying spacecraft. Research teams involved in this program are located at universities, industrial laboratories, NASA field centers, and other government laboratories.

The scientific information obtained and the technology developed in this program are made available to the scientific communities for application to and the advancement of scientific knowledge, education and technology.

The Physics and Astronomy missions undertaken to date have been extraordinarily successful, and a number of missions continue to produce a rich harvest of scientific data; the International Ultraviolet Explorer (IUE) and the Solar Maximum Mission (SMM) are still operating, and new scientific results are continually emerging from the analysis of the High Energy Astrophysics Observatories (HEAO) and Infrared Astronomical Satellite (IRAS) data sets.

Explorer satellites are relatively low cost but extremely effective missions which have been developed and launched since the beginning of our country's space program. Our most recent Explorer misssion, the Infrared Astronomical Satellite (IRAS), developed in collaboration with the Netherlands and the United Kingdom, was launched in January 1983. In carrying out the first survey of the far infrared sky, IRAS made exciting discoveries and significant contributions to astronomical research as it observed the cool and obscured objects of the universe. These objects include cool matter around the stars, heretofore undetected comets, regions of star formation, and dust rings in our planetary system. A catalog will be published this year with many thousands of infrared sources identified.

In FY 1985, the development activities of the Space Telescope will be continued in preparation for launch in 1986. The major activity during FY 1985 will be the assembly and verification of the total Space Telescope system. The Gamma Ray Observatory system Critical Design Review will be held in FY 1985, and major fabrication efforts on spacecraft and instrument systems will be continued.

Two major Explorer missions are now under development: the Active Magnetospheric Particle Tracer Explorers (AMPTE) and the Cosmic Background Explorer (COBE). In addition, a U.S. X-ray high resolution imager is being developed for launch on the Roentgen Satellite (ROSAT), which is being developed by the Federal Republic of Germany. Development of the Extreme Ultraviolet Explorer (EUVE) which will be initiated in FY 1984, will allow a survey of the sky in the last unmapped spectral band by covering the portion of the electromagnetic spectrum between ultraviolet and X-rays.

The Spacelab 1 mission was successfully flown in late 1983, and provided exciting proof of the viability of conducting experiments on-board the Space Transportation System. The Materials Experi-

mental Assembly instrumentation was also flown in later 1983 and good results were obtained. Effort is continuing on Spacelab 2, second of the two verification flights of the Spacelab. Spacelab 3, primarily a materials processing and life sciences mission, will be flown in late 1984, and will include the first flight of the Fluid Experiment System/Vapor Crystal Growth instrumentation. In addition, sounding-rocket-type of instrumentation will be developed to be flown on the Space Transportation System to allow longer flight times of these low-cost instruments.

Suborbital observations will continue to be conducted in FY 1985 from balloons, sounding rockets, and high-flying aircraft that carry instruments above most of the atmosphere.

### Space Telescope Development

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Spacecraft | $174,800,000 |
| Experiments | 20,200,000 |
| Total | 195,000,000 |

The Space Telescope will make a major contribution to understanding the stars and galaxies, the nature and behavior of the gas and dust between them, and the broad question of the origin and scale of the universe. Operating in space above the atmospheric veil surrounding the Earth, the Space Telescope will increase, by several hundredfold, the volume of space accessible for observations. With its significant improvements in resolution and precision in light sensitivity and in wavelength coverage, the Space Telescope will permit scientists to conduct investigations that could never be carried out with ground-based observatories limited by the obscuring and distorting effects of the Earth's atmosphere.

The Space Telescope will enhance the ability of astronomers to study radiation in the visible and ultraviolet regions of the spectrum. It will be more sensitive than ground-based telescopes and will allow the objects under study to be recorded in greater detail. It will make possible observations of objects so remote that the light will have taken many billions of years to reach the Earth. As a result, we will be able to look far into the distant past of our universe. The Space Telescope will also contribute significantly to the study of the early state of stars and the formation of solar systems, as well as the observation of such high-evolved objects as supernova remnants and white dwarf stars. With the Space Telescope we may be able to determine the nature of quasars and the processes by which they emit such enormous amounts of energy; it may also be possible to determine whether some nearby stars have planetary systems.

The Space Telescope will be an automated observatory, delivered into orbit by the Space Shuttle. Data from its scientific instruments will be transmitted to Earth via the Tracking and Data Relay Satellite System. The Space Telescope design will permit in-orbit maintenance and repair, and/or retrieval by the Space Shuttle for return to Earth for required refurbishment and then relaunch by the Space Shuttle.

During FY 1983, the Primary Mirror Assembly was completed and integration of the Optical Telescope Assembly began. Most of the Support System Module has been fabricated. All of the scientific instruments have been delivered to the Goddard Space Flight Center for verification and acceptance testing, which is now in progress.

In FY 1984, the Space Telescope system fabrication, integration and testing efforts will continue. In particular, the Optical Telescope Assembly (OTA) integration and testing activities will be continued, leading to delivery of the OTA to Lockheed in early FY 1985 for integration with the Support Systems Module.

The FY 1985 funding is required to complete the integration and testing of the Optical Telescope System and its subsequent delivery to Lockheed where it will be integrated with the Support Systems Module. In addition, the entire Space Telescope system integration and testing will be initiated leading to the launch of the ST in the second half of 1986 rather than the first half of 1985 due to technical problems encuntered during FY 1983, particulary with the Optical Telescope Assembly.

## Gamma Ray Observatory Development

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Spacecraft | $101,700,000 |
| Experiments | 18,500,000 |
| Total | 120,200,000 |

The objective of the Gamma Ray Observatory mission is to measure gamma radiation from the universe, and to explore the fundamental physical processes powering it. Certain celestial phenomena are accessible only at gamma ray energies. The observational objectives of the Gamma Ray Observatory are to search for direct evidence of the synthesis of the chemical elements; to observe high energy astrophsical processes occurring in supernovae, neutron stars and black holes; to locate gamma ray burst sources; to measure the diffuse gamma ray radiation for cosmological evidence of its origin; and to search for unique gamma ray emitting objects.

Cosmic gamma rays represent one of the last frontiers of the electromagnetic spectrum to be explored. The low flux levels of gamma ray quanta, and the high background they produce through their interaction with the Earth's atmosphere, coupled with the demand for better spectral, spatial and temporal resolution of source features, combine to require that large gamma ray instruments be flown in space for a prolonged period. Gamma rays provide unique information on the most intriguing astronomical objects yet discovered, including quasars, neutron stars, and black holes.

The Gamma Ray observatory is scheduled for launch by the Space Shuttle in 1988. The spacecraft is being designed to accomodate four large gamma ray instruments, and will be designed to allow maintenance and retrieval by the Space Shuttle. The instruments will have their principal axis pointed in the same direction, and the spacecraft will point these instruments in a fixed direction in space for long periods (hours to weeks).

In FY 1983, preliminary design reviews for the instruments were completed. Procurement of long-lead hardware for the spacecraft was initiated, as was detailed spacecraft design, including definition of interfaces with the Space Shuttle. In FY 1984, instrument critical design reviews will be held for the instruments, as will the preliminary design review for the spacecraft. In addition, fabrication of the spacecraft and instrument hardware will be initiated.

The FY 1985 funding is required for continuation of the major frabrication and assembly efforts on both the instruments and the spacecraft, and for completion of the total mission critical design review.

## Shuttle, Spacelab Payload Development and Mission Management

### FISCAL YEAR 1985 FUNDING LEVEL

Payload Development and Mission management ..... $109,400,000

The objectives of Spacelab payload development and mission management are to develop instruments in order to conduct experiments and acquire new knowledge in the disciplines of physics and astronomy, to develop experiment interface hardware for materials processing, to develop sounding rocket class payloads for flight on the Space Shuttle, and to manage the mission planning and execution of all NASA Spacelab payloads. This project supports the development of all physics and astronomy experiments; system management and engineering development of flight equipment and software; payload specialist training and support; physical integration of the payloads with the Spacelab system; operation of the payloads in flight; dissemination of data to experimenters; and analysis of physics and astronomy flight data. In addition, this project funds the mission management efforts for all NASA Spacelab payloads.

Instruments are currently under development for several Shuttle/Shuttle/Spacelab misions with primary emphasis on physics and astronomy. The Spacelab 2 mission, which is the second verification flight of the European-built Spacelab, is scheduled to fly in 1985. The objectives of Spacelab 2 are to verify the Spacelab pallet and igloo systems, and to obtain scientific data with emphasis on astrophysics and solar physics. The Instrument Pointing System, developed by the European Space Agency, will be flown for the first time on Spacelab 2.

Three ultraviolet telescopes are also currently in development leading to a launch in 1986 (ASTRO–1). This mission is designed to conduct investigations in ultraviolet imaging, spectrophotometry, and polarimetry at very high resolution. The ASTRO–1 mission will also carry two wide-field cameras, to conduct unique scientific observations of Halley's Comet in the near-Earth environment. ASTRO–1, as well as reflights of this instrumentation, are designed to allow scientific investigations of a broad range of objects, from nearby comets and planets to the most distant quasars.

The Solar Optical Telescope (SOT) definition is being continued in FY 1984. The SOT will provide extremely high resolution images of the Sun's surface and atmosphere, permitting for the first time

measurement matched to the spatial scale of fundamental solar phenomena.

Mission management activities are continuing on several space science and applications missions, for example, OSTA-3, several materials processing payloads, and the first dedicated Life Sciences mission (Spacelab 4).

The Spacelab 1 mission was successfully flown in early FY 1984, providing exciting proof of the viability of conducting experiments on-board the STS. The first flight of the Materials Experiment Assembly also took place. Spacelab 3, primarily a materials processing an life sciences mission, will be flown in early 1985. One of the major experiments which will be flown on Spacelab 3 is the Fluid Experiment System/Vapor Crystal Growth.

In FY 1985, mission management of the ongoing Spacelab missions will be continued. Mission management for the non-physics and astronomy missions includes all Spacelab efforts except instrument development and data analysis on approximately eighteen different payloads. Definition of the Solar Optical Telescope will be continued in FY 1985, and development of the Space Plasma Lab will be continued. In addition, FY 1985 funding is required for the continuation of development and testing activities on the Spacelab 2 hardware, hardware for three ultraviolet telescopes which will be flown on ASTRO-1 in 1986, on OSS-2 which will be flown in 1987 and refurbishment of some hardware which were flown on Spacelabs 1 and 2. FY 1985 funding is also required for the development of low-cost sounding rocket class payloads which will be flown on the Space Shuttle to provide more flight opportunities to the science community at a relatively low cost.

## Explorer Development

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Cosmic background explorer | $32,600,000 |
| Roentgen satellite | 1,100,000 |
| Extreme ultraviolet explorer | 15,000,000 |
| Other explorers | 3,200,000 |
| Total | 51,900,000 |

The Explorer program provides the principal means of conducting those astronomical studies and long-term investigations of solar physics and of the near-Earth interplanetary environment which have limited specific objectives and which do not require major observatories. Included in the present program are studies of atmospheric and magnetospheric physics; the several magnetospheric boundaries; interplanetary phenomena; cosmic ray investigations; and X-ray, ultraviolet and infrared astronomy. Studies are conducted to define future high priority science explorer missions. NASA engages in cooperative missions with other federal agencies and other nations whenever such cooperation will assist in achieving the mission objectives.

Solar terrestrial and atmospheric explorers provide the means for conducting studies of the Earth's near-space environment. The program requires a wide variety of satellites in orbits extending from the very lowest reaches of the upper atmosphere to the interplanetary medium beyond the Earth's magnetosphere. Efforts in

FY 1984 include launch of the San Marco-D mission, and launch of the Active Magnetospheric Particle Tracer Explorer. The San Marco-D mission, a cooperative project with Italy, will include a group of U.S. experiments to study the relationship between solar activity and the Earth's meteorological phenomena. The Active Magnetospheric Particle Tracer Explorer, a cooperative project with the Federal Republic of Germany, consists of two spacecraft, one built by the United States and one built by Germany. The mission will study the solar wind at the subsolar point and will identify particle entry windows, energization processes and transport processes into the magnetosphere.

Astrophysics explorers have been instrumental in conducting the first astronomical sky surveys in the gamma ray, X-ray, ultraviolet, infrared, and low frequency radio regions of the electromagnetic spectrum. A prime example is the Infrared Astronomical Satellite, which has just completed a highly successful survey mission. In FY 1984, development will continue on the Cosmic Background Explorer (COBE), and on the X-ray imaging instrument to be flown on the German Roentgen Satellite (ROSAT). COBE will carry out a definitive, all-sky exploration of the infrared background radiation of the universe between the wavelengths of 1 micrometer and 9.6 millimeters. The detailed information which the COBE will provide on the spectral and spatial distribution of low energy background radiation is expected to yield significant insight into the basic cosmological questions of the origin and evolution of the universe. ROSAT, a cooperative project between the Federal Republic of Germany and the United States, will perform high resolution imaging studies of the X-ray sky. The United States will provide a high resolution imaging instrument and launch services, and Germany will provide the spacecraft and other instrumentation.

Work is also continuing in FY 1984 on the Cosmic Ray Isotope Experiment (CRIE). The CRIE sensor, which will be launched in 1986 on a Department of Defense spacecraft, will study galactic cosmic rays and accelerated nuclei from solar flares. In addition, instrumentation development is being continued for the reflight of the Long Duration Explosure Facility to gather data on the relative energies and abundances of the rarer heavy cosmic ray nuclei. This spacecraft will be launched in 1986 by the Space Shuttle, with subsequent retrieval about two years later. In addition, funding in FY 1984 will support initiation of the Extreme Ultraviolet Explorer (EUVE), which will carry out the first detailed all-sky survey of ultraviolet radiation between 100 and 900 angstroms—a hitherto unexplored portion of the electromagnetic spectrum.

FY 1984 funding is also supporting definition studies for future candidate explorer missions, including the X-ray Timing Explorer and the Far Ultraviolet Spectroscopy Explorer. Studies are also being conducted on potential alternate lower cost spacecraft concepts for future explorers.

FY 1985 funding is required for continued development activity on the Cosmic Background Explorer, the Extreme Ultraviolet Explorer, the ROSAT instrument, the Cosmic Ray Isotope Experiment, and the instrumentation for the reflight of the Long Duration Exposure to obtain cosmic ray data. FY 1985 funding will also provide for definition studies of future potential explorer missions.

## Mission Operations and Data Analysis

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| High energy astronomy observatory extended mission | $5,000,000 |
| Solar maximum mission extended mission | 1,500,000 |
| Solar maximum mission retrieval/repair mission | 7,500,000 |
| Space telescope operations | 49,000,000 |
| Space telescope maintenance and refurbishment | 25,700,000 |
| Explorers | 20,400,000 |
| Total | 109,100,000 |

The purpose of the mission operations and data analysis effort is to conduct operations and analyze data from the physics and astronomy spacecraft after launch. The program also supports the continued operation of a number of spacecraft after their originally planned objectives have been achieved, for purposes of conducting specific investigations that have continuing, high scientific significance. The funding supports the data analysis activities of the many investigators at universities and other research organizations associated with astrophysics and solar terrestrial operational satellite projects. Actual satellite operations, including operation control centers and related data reduction and engineering support activities, are typically carried out under a variety of mission support or center support contracts.

In addition to the normal support required for mission operations, the Space Telescope program encompasses several unique aspects which must be provided for well in advance of launch. The Space Telescope is designed for operation for more than a decade, using the STS for in-orbit maintenance of the spacecraft and in-orbit changeout or repair of the scientific instruments. Also planned for the Telescope is periodic retrieval, return to Earth for complete refurbishment, and then relaunch by the Space Shuttle. During the period, the Space Telescope will be used primarily by observers selected on the basis of proposals submitted in response to periodic solicitations. Science operations will be carried out through an independent Space Telescope Science Institute. The Institute will operate under a long-term contract with NASA. While NASA will retain operational responsibility for the observatory, the Institute will implement NASA policies in the area of planning, management, and scheduling of the scientific operations of the Space Telescope.

FY 1985 funds will provide support for the basic mission operations and data analysis activities for the Active Magnetospheric Particle Tracer Explorer, continued operation and data analysis activities for the International Ultraviolet Explorer, and continued analysis of the extensive data obtained by the Infrared Astronomical Satellite and the High Energy Astronomy Observatories. FY 1985 funding will provide for the continued operation of the repaired Solar Maximum Mission, and preparation for the operation of the Space Telescope. In FY 1985, the development of mission operations procedures as well as development of the science operations ground system for the Space Telescope will be continued. The Space Telescope Science Institute activities will be continued leading to operational capability through the continued development of the Guide Star Selection System and Science Data Analy-

sis Software. In FY 1985, maintenance and refurbishment planning activities such as the purchase of orbital replacement units and space support equipment will be continued to allow for the capability to service the Space Telescope in orbit.

## Research and Analysis

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Supporting research and technology | $26,400,000 |
| Advanced technology development | 11,000,000 |
| Data analysis | 5,500,000 |
| Total | 42,900,000 |

This program provides for the research and technology base necessary to define, plan and support flight projects. Preliminary studies to define missions and/or payload requirements are carried out, as are theoretical and ground-based supporting research and advanced technology development (ATD). Activities included are supporting research and technology (SR&T), ATD, and data analysis.

*Supporting Research and Technology (SR&T).*—The objectives of supporting research and technology are to: (1) optimize the return expected from future missions by problem definition, development of advanced instrumentation and concepts, and sound definition of proposed new missions; (2) enhance the value of current space missions by carrying out complementary and supplementary ground-based observations and laboratory experiments; (3) develop theories to explain observed phenomena and predict new ones; and (4) strengthen the technological base for sensor and instrumentation development and conduct the basic research necessary to support our understanding of astrophysics and solar-terrestrial relationships.

Research is supported in the disciplines of astronomy, astrophysics, gravitational physics, and solar and heliospheric physics. Research in astronomy and astrophysics involves the study of stars, galaxies, interstellar and intergalactic matter, and cosmic rays. The work in solar and heliospheric physics involves the study of the solar atmosphere and the influence of the Sun on interplanetary phenomena. The development of new instruments, laboratory and theoretical studies of basic physical processes, and observations by ground-based and balloon-borne instruments are also supported. Results achieved in the SR&T program have a direct bearing on future flight programs. For example, the development of advanced X-ray and ultraviolet astronomy imaging devices under this program will enable spacecraft to carry instruments for astronomical observations which have increases of orders of magnitude in sensitivity and improved resolution over currently available detectors.

The SR&T program carries out its objectives through universities, non-profit and industrial research institutions, NASA centers and other government agencies. Current emphasis is being placed on studies of advanced instrumentation with increased sensitivity and resolution.

*Advanced Technological Development (ATD).*—The advanced technological developemnt activities support detailed planning and definition of new potential physics and astronomy missions. ATD

activities assure that future missions address the scientific questions most important to the evolution of knowledge in the field, and that those missions use the appropriate technology and techniques. Funding is applied to the definition and preliminary design for specific missions or subsystems and elements critical to eventual mission development in order that technical readiness and resources may be adequately defined before the missions are proposed for implementation.

Candidate missions for the 1980's and early 1990's that require ATD activities include the Advanced X-Ray Astrophysics Facility (AXAF), the Solar Dynamics Observatory (SDO) and the Starprobe. The AXAF mission, which is the first priority mission recommendation of the National Academy of Sciences, will study stellar structure and evolution, active galaxies, clusters of galaxies and cosmology. The AXAF's 1.2 meter class imaging X-ray telescope is planned to have a sensitivity approximately 100 times that of HEAO-2 and a resolution increase of nearly a factor of twenty. The SDO will observe the oscillations visible on the Sun and use the data to investigate the dynamics of the Sun's interior in order to provide insight into solar and stellar interior structure. The Starprobe mission will perform detailed scientific observations of the Sun from a highly elliptical orbit whose aphelion will be within three solar radii of the Sun's surface.

Major Spacelab payloads being considered for future missions and requiring advanced technological development support include the following multi-user facilities: the Pinhole/Occulter Facility, a coded mask and detector for imaging hard X-rays; and the Shuttle Ultraviolet/Optical Telescope, a meter-class ultraviolet/optical facility which will be used for high angular resolution imaging investigations of sources that have too great an angular extent to be observed efficiently with the Space Telescope.

During FY 1984, major emphasis is being given to definition of the AXAF mission, while definition work is also continuing on Spacelab instruments and facilities, including detailed description of payload configurations and operational requirements.

*Data Analysis.*—The acquisition, analysis and evaluation of data represents the primary purpose of the laboratory, balloon, rocket and spacecraft activities. While a considerable amount of analysis is done during the prime project phase, experience has shown that considerably more time is required to reap the full benefit from these programs. This will come about only when the data is correlated with other projects, when detailed cause-and-effect studies are made with data sets from other sources, when very long-term (e.g., one solar cycle) effects can be studied by using complementary sets of data, and when new ideas that originate from the results of the initial analysis can be tested. For example, astronomical image processing facilities have been developed to take advantage of high technology developed under the Landsat and planetary programs. This technology allows astronomers to extract a maximum amount of information from the data they obtained from standard photographic emulsions and more advanced imaging techniques such as the charge-coupled devices now being ground tested for use on the Space Telescope.

During FY 1985, the supporting research and technology program will support those tasks which contribute to maintaining a firm base for a viable physics and astronomy program. Emphasis will be placed on infrared detector development and on expansion of technology activities related to large X-ray mirrors, advanced X-ray detectors, gamma ray spectrometers and instrumentation. Emphasis will also be placed on the development of a large array multi-channel plate, and on intensified charge-coupled imagery devices. In the area of solar physics, activities will support the Solar Maximum Mission, especially through theoretical studies of high energy phenomena. Thrusts in the development of advanced generation instrument concepts will continue especially for the extreme ultraviolet and X-ray wavelengths, and for analyzing the structure and dynamics of the solar interior. FY 1985 funding will also support continued feasibility and definition studies on future potential candidate missions such as the Advanced X-ray Astrophysics Facility.

FY 1985 funding will also support continued feasibility and definition studies on future potential candidate missions such as the Advanced X-ray Astrophysics Facility and the Solar Dynamics Observatory as well as the definition of new Spacelab payloads. In the data analysis activities to be carried out at universities and government research centers in FY 1985, emphasis will be placed on correlative studies involving data acquired from several sources (spacecraft, balloons, sounding rockets, research aircraft and ground observatories).

## Suborbital Programs

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Sounding rockets | $29,500,000 |
| Airborne science and applications | 22,000,000 |
| Balloon program | 7,200,000 |
| Total | 58,700,000 |

The suborbital program uses balloons, aircraft, and sounding rockets to provide versatile, relatively low cost research on the Earth's ionosphere and magnetosphere, space plasma physics, stellar astronomy, solar astronomy, and high energy astrophysics. Activities are conducted on both a domestic and an international cooperative basis.

*Sounding rockets*

A major objective of the sounding rocket program is to support a coordinated research effort. Sounding rockets are uniquely suited for performing low altitude measurements (between balloon and spacecraft altitude) and for measuring vertical variations of many atmospheric parameters. Special areas of study supported by the sounding rocket program include the nature, characteristics, and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including the production of aurorae and the coupling of energy into the atmosphere; and the nature, characteristics, and spectra of radiation of the Sun, stars and other celestial objects.

Additionally, the sounding rocket program provides the physics and astronomy program with the means for flight testing instruments and experiments being developed for later flight on the Shuttle/Spacelab and space probes, and for calibrating and obtaining vertical profiles in concert with current orbiting spacecraft.

In FY 1983, 53 rockets were launched from five launch ranges located in the United States, Canada, and Peru. These rockets supported the research activities of about 26 groups from over 18 universities, NASA field centers, other government agencies, and foreign research groups.

One highlight of the FY 1983 program was a highly successful international campaign with Peru to study the properties of the middle atmospheric electrodynamics and aeronomy in the equatorial region. This campaign included the launch of 18 major sounding rockets from Chilca, Peru. One of the significant findings from this campaign is that the electrical conductivity of the middle atmosphere increases in response to radiation received from the X-Ray star Sco-X-1.

In FY 1984, NASA will place emphasis on the transition from sounding rockets to the Shuttle of some of the sounding rocket class payloads in the disciplines of high energy astrophysics, solar physics, and ultraviolet astronomy. FY 1985 funds will provide for continuation of the sounding rocket program described above.

*Airborne science and applications*

Research with instrumented jet aircraft has been an integral part of the overall NASA program in physics and astronomy since 1965. For astronomy research, the airborne science and applications program utilizes a C-141 instrumented with the 91-centimeter infrared telescope. The C-141A "Kuiper Airborne Observatory", which began operational flights in 1974, is a full-scale, manned facility. This aircraft provides a large payload capacity and facilities for extending observations over any region of the Earth, and can operate at high altitudes (nearly 13 kilometers), in order to provide a cloud-free site for astronomical observations and auroral geophysics experiments. The possibility of conducting observations at this altitude, above most of the infrared-absorbing water vapor of the Earth's atmosphere, has been essential to astronomy in opening the infrared region of the electromagnetic spectrum from one micrometer to hundreds of micrometers.

In FY 1983, 72 flights were flown to make far-infrared observations, including an expedition to Australia to observe the center of our own galaxy. In FY 1984, approximately 64 flights of the C-141 will be made to continue exploration in the star-forming regions. Data gathered by the Infrared Astronomical Satellite will be used extensively to determine targets of observation. A complete overhaul of the C-141 will also be carried out in compliance with Federal Aviation Administration requirements.

This program also provides flight support to other major segments of the Space Science and Applications program, with an aircraft fleet currently consisting of U-2C's, one ER-2, one C-130, one CV-990, and a Learjet. These aircraft serve as test beds for newly developed instrumentation and permit the demonstration of new sensor concepts prior to their flight on satellites and the Spacelab.

The data acquired during these flights are used to refine algorithms and develop ground data handling techniques. An example of such activities is flights in the ER-2/U-2C's to acquire simulated thematic mapper data. Another principal use of the ER-2/U-2C's is to acquire stratospheric air samples and conduct *in situ* measurements at altitude ranges above the capability of more conventional aircraft and below orbiting satellites. This use is important in the study of stratospheric transport mechanisms.

IN FY 1985, the airborne science and applications funding will be used to continue operation of the Kuiper Airborne Observatory, to support astronomical groups, and to continue the development of improved instrumentation for conducting infrared astronomy. Funding will also be used to fly the U-2C's, ER-2, Learjet, and CV-990, consistent with the approved aircraft flight program.

*Balloon program*

For the develpment of scientific experiments for space flight and for independent scientific missions, it is desirable to test the instrumentation in the space radiation environment and to make observations at altitudes which are above most of the obscuring effects of the atmosphere, particularly for observations in infrared, gamma ray, and cosmic ray astronomy. In many instances it is necessary, because of size and weight, as well as low cost, to fly these experiments on balloons.

The balloon program funding is required for purchase of balloons, helium, launch services, tracking and recovery, and maintenance and operation of the National Science Balloon Facility (NSBF) at Palestine, Texas. This facility supports the launch of over 95 percent of NASA's balloon payloads, and it is the nation's primary means for carrying out large scientific balloon operations. NASA assumed total funding responsibility for the NSBF, including administrative costs, from the National Science Foundation at the beginning of FY 1984. Funding for the experiments which are flown on balloons is provided from supporting research and technology programs.

In FY 1983, 44 balloons were flown from launch sites in the United States and Brazil. Over 95 percent of the flights originated in the United States. During FY 1983, the development of a tethered balloon capability for investigating atmosphere electrodynamics was completed. Three missions were completed with the last one providing four days of flight data.

In FY 1984, approximately 60 balloon flights are planned to continue scientific research in the areas of atmospheric chemistry, high energy astrophysics, galactic astronomy and solar studies.

The FY 1985 funding will provide for the continuation of the balloon program as well as management and operation of the NSBF. This funding is also required to continue definition activities on potential future long duration balloon flights.

**4. LIFE SCIENCES PROGRAM $63,300,000**

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Life sciences flight experiments | $27,100,000 |
| Life sciences research and analysis | 36,200,000 |
| Total | 63,300,000 |

The goals of the Life Sciences program are to provide a sound scientific, medical, and technical basis for safe and effective manned space flight, and to advance the understanding of the basic mechanisms of biological processes by using the unique capabilities of the space program. Results from the research program are applied to: the immediate needs in the maintenance and health of the astronauts; understanding the response of biological systems to weightlessness; the design of the advanced life support systems for use on future missions; and understanding the biosphere of the planet Earth, its origin, evolution, and present state.

The Life Sciences program is the key to developing a capability to sustain a permanent manned presence in space and to utilize the space environment to study living systems. These activities include both ground-based and space research efforts which are mutually supportive and integrated, and use a composite of disciplines and techniques in both biology and medicine to address space-related medical problems and fundamental biological processes.

The Life Sciences research and analysis program includes several major elements: operational medicine, which is focused on the health and well being of Space Shuttle crews; biomedical research, which is directed toward understanding and preventing any adverse physiological changes which occur in space flight; advanced life support systems, which is a program of research and technology development for life support systems necessary to maintain life in space autonomously for long periods of time; gravitational, biology, which consists of flight and ground-based experiments that focus on using microgravity as a biological research tool to understand its effect on plants and animals; exobiology research, which is directed toward understanding the origin and distribution of life and life-related molecules on Earth and throughout the universe; and biospheric research, which is directed toward understanding the interaction between life on Earth and its physical and chemical environment.

## Life Sciences Flight Experiments

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Life sciences flight experiments | $27,100,000 |

The objective of the Life Sciences Flight Experiments program is to assimilate information and scientific questions from the various life sciences disciplines translate them into payloads designed to expand our understanding of the basic physiological mechanisms involved in adaptation to weightlessness. The program includes selection, definition, inflight execution, data analysis, and reporting of medical and biological investigations. Past experience indicates that humans clearly undergo physiological changes in weightlessness. Thus far these changes appear to be reversible upon return to Earth; however, many of the observed changes are physiologically significant and are not well understood. With weightless exposure beyond several months, these changes may prove irreversible. Early Shuttle/Spacelab missions are suitable for gaining a greater

understanding of the early response to weightlessness, which will improve the management of several existing problems (e.g., space adaptation syndrome) and will enhance the confidence of estimating the physiological consequences of more sustained weightless exposure

Current activities involve the development of life sciences flight experiments to be flown on Spacelabs 2, 3, and 4 and the German-D1 mission (Spacelab-D1). Most of the experiments onboard the early Shuttle flights will serve as pathfinding activities for Spacelab-4, the first Spacelab mission dedicated entirely to life sciences investigations. Hardware and experimental protocols for flights through Spacelab-3 are well developed. Activities on Spacelab-3 will involve evaluation of functional performance and compatibility of hardware that is essential to human and animal investigations which will be conducted on Spacelab-4. Hardware development and mission planning activities are proceeding on schedule for the United States vestibular experiment which will be flown on the German-D1 mission; these are follow-up investigations to those conducted on Spacelab-1.

Twenty-four investigations have been tentatively selected for flight on Spacelab-4. The definition phase activities have been completed and the design and development of the flight hardware is well underway. These investigations have been combined into a comprehensive, integrated exploration of the known problems of manned space flight through the use of both human and animal subjects, and key scientific investigations in gravitational biology. Teams of principal investigators will examine cardiovascular adaptation, space adaptation syndrome, muscle atrophy, demineralization of bone, the early anemia of weightlessness, and the effects of weightlessness on plant and animal development. These missions will be unique in several respects: they will be the first Shuttle/Spacelab missions dedicated entirely to life sciences; they will involve highly skilled scientists as payload specialists, permitting the use of numerous experimental techniques and procedures never before utilized in space; and the experiments will employ complementary human and animal investigations in order to validate models for human physiology

FY 1985 funding is required for the continuing definition and development of hardware which will be flown on future Spacelab missions, i.e., Spacelab-3 D1, 4 and the second dedicated life sciences mission, yet to be designated. Flight hardware integration and experiment development associated with Spacelab-2, 3, and D1 will be completed in preparation for launches in 1984 and 1985. We are now in the process of final experiment selection of investigations for the first life sciences dedicated mission (Spacelab-4). In addition, the selection process for experiments for the follow-on dedicated Spacelab life sciences missions has been initiated through the recent release of a new flight Announcement of Opportunity (AO).

### Life Sciences Research and Analysis

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Life sciences research and analysis | $36,200,000 |

The research and analysis activity of the Life Sciences program is concerned, in part, with ground-based research in basic biology and in those medical problem areas that affect manned spaceflight. The program is comprised of six elements: (1) operational medicine; (2) biomedical research; (3) advanced life support systems research; (4) gravitational biology; (5) exobiology; and (6) biospheric research.

The Life Sciences Operational Medicine program is responsible for bringing the science, technology, and practice of medicine to bear on solving the problems of sustaining, supporting, and protecting individuals working in the space environment. The program provides the means for assuring the physical welfare, performance, and adequate treatment of in-flight illnesses or injuries. Such conditions as spatial disorientation and fluid and endocrine shifts which can decrease performance, cardiovascular tolerance, and possibly aggravate latent diseases, will be carefully monitoried to determine preventive measures. To this end, careful medical selection, periodic evaluation of health status, and in-flight monitoring of the time required for adaption to the space environment will be continually undertaken.

The Biomedical Research program seeks to develop the basic medical knowledge needed to enable men and women to operate more effectively in space. The program is organized into discrete elements, each designed to rectify a particular physiological problem known or expected to affect the human organism in space. Such problems as motion sickness, bone loss, and electolyte imbalances are under intense scrutiny not only to provide a better understanding of their underlying causes, but also to develop more effective preventive measures. The program makes extensive use of ground-based simulation techniques which evoke, in both humans and animals, physiological changes similar to those seen in space.

The Advanced Life Support System research program concentrates on enhancing our ability to support long-duration manned presence in space and on optimizing the productivity of the STS crews. Improvements are sought in spacecraft habitability and man-machine system engineering methods as well as a means to provide air, water, and food to support life directly. The program has developed technology for building apparatus to regenerate spacecraft air and water supplies in flight and is investigating the scientific basis for new systems such as food recycling for long-term missions. Research is in progress on space suits for quick reaction situations and on innovative approaches to designing space tools and work stations.

The Gravitational Biology program explores the role of gravity in life processes and uses gravity as an environmental tool to investigate fundamental biological questions. Specific objectives are to: (1) investigate and identify the role of gravity in plant and animal behavior, morphology and physiology; (2) identify the mechanisms of gravity sensing and transmission of gravity perception information within both plants and animals; (3) identify the interactive effects of gravity and other stimuli (e.g., light) and stresses (e.g., vibration and disorientation) on the development and metabolism of organisms; (4) use gravity to study the normal nature and properties of living organisms; and (5) to extend the limits of knowledge about

plant and animal growth as well as long-term survival and reproduction of life in space.

The Exobiology program is directed toward furthering our understanding of the origin and evolution of life, and life-related molecules, on Earth and elsewhere in the universe. Research, in general, builds on data acquired by missions in planetary exploration and astrophysics to uncover the relationship between the origin and evolution of the solar system and life itself. Theoretical and laboratory investigations are also included in this program to develop a better understanding of the conditions on the primitive Earth as related to early chemical and biological evolution.

The Biospheric Research program explores the interaction between the biota and the contemporary environment to develop an understanding of global bio-geochemical cycles. Laboratory and field investigations are correlated with remote sensing data to characterize the influence of biological processes in global dynamics. Biospheric modelling efforts are focused on integrating biology with atmospheric, climatic, oceanic, terrestrial, and bio-geochemical cycling data to reflect the state of the biosphere as a function of both natural and anthropogenic perturbations.

In FY 1985, the Operational Medicine program will collect information on occupational exposures in zero-gravity on each Shuttle flight; conduct inflight clinical testing of countermeasures especially in the areas of cardiovascular deconditioning and vestibular problems, and develop health care procedures compatible with the space environment. Medical data will be evaluated in order to better define responses of different population groups to space flight.

In FY 1985, the Biomedical Research program will focus primarily on problems related to vestibular dysfunction because of the high incidence of space adaptation syndrome in Shuttle operations. Psychology, human factors, and the enhancement of performance and efficiency among flight crews are all receiving increased emphasis. Studies of bone loss and of electrolyte imbalance will also be pursued so that potential countermeasures can be devised. Increased exposure to, and awareness and understanding of, the potential radiation hazard from space flight has resulted in more emphasis being placed on the precise measurement of radiation doses, the specific biological effects of cosmic rays, and the identification of possible radiation shielding.

In FY 1985, the Advanced Life Support Systems program will continue to investigate basic biological processes and physical methods to recycle air, water, food and biological waste; and continue definition of concepts for improved space suits and portable life support systems.

In FY 1985, the Gravitational Biology program will focus on continuation of research directed at understanding animal and plant equilibrium gravity perception, and biotransduction mechanisms, as well as gravity's effect on plant and animal development, structure, and behavior. Increased emphasis will be placed on research that will lead to the development of hypotheses, and provide baseline data for future Shuttle/Spacelab flight experiments.

In FY 1985, the Exobiology program emphasis will be placed on the continuation of such efforts as expanding our knowledge of

non-biological mechanisms for synthesis of biologically significant molecules both in space and on the Earth. This research is crucial for gaining further insight into the origin of life, assessing the possibility of these processes occurring elsewhere in the universe, and preparing for future flight experiments.

In FY 1985, the Biospheric Research program will place emphasis on improving our estimating techniques for determining the size and distribution of the terrestrial biomass by combining ground-based measurements with remote sensing data. Additional emphasis will be placed on characterizing biogenic gas fluxes of key atmospheric constituents. This information is required for the development of a better understanding of global bio-geochemical cycles.

In FY 1985, emphasis will also be placed on the formulation of improved approaches to the operational management of space adaptation syndrome. In-flight evaluation of these approaches will be conducted to provide the basis for the development of more effective countermeasures. An interdisciplinary approach to determining how to enhance the capabilities. performance and efficiency of spaceflight crews will also be undertaken. The object of this effort will be to allow humans, to the fullest extent possible, the opportunity to explore and work in space by improving the working environment and by facilitation of the human interaction with the automated devices that can be placed at their disposal.

**5. PLANETARY EXPLORATION, $296,900,000**

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Galileo develpment | $56,100,000 |
| Venus radar mapper mission | 92,500,000 |
| International solar polar mission | 9,000,000 |
| Mars Geoscience/Climatology Orbiter (MGCO) | 16,000,000 |
| Mission operations and data analysis | 58,800,000 |
| Research and analysis | 64,500,000 |
| Total | 296,900,000 |

The Planetary Exploration program encompasses the scientific exploration of the solar system including the planets and their satellites, comets and asteroids, and the interplanetary medium. The program objectives are: to understand the origin and evolution of the solar system, to understand the Earth better through comparative studies with the other planets, and to understand how the appearance of life in the solar system is related to the chemical history of the solar system. Projects undertaken in the past have been highly successful. The strategy that has been adopted calls for a balanced emphasis on the terrestrial-like inner planets, the giant gaseous outer planets, and the small bodies (comets and asteroids). Missions to these planetary bodies start at the level of reconnaissance to achieve fundamental characterization of the bodies, and proceed to a level of detailed study. The reconnaissance phase of inner planet exploration began in the 1960's and has now been completed, though we still know little about the nature of the planet Venus' surface. Mars has provided program focus because of its potential as a site of biological activity. The Viking landings in 1976 carried the exploration of Mars forward to a high level of scientific and technological achievement, thereby setting the stage for

the next step of detailed study. Analyses of the lunar rock samples returned by Apollo continue to be highly productive as new insights into the early history of the inner solar system are achieved and our theoretical concepts are revised accordingly. The continuing Pioneer Venus mission is carrying the study of our nearest neighbor and closest planetary analogue beyond the reconnaissance stage to the point where we have produced a basic characterization of the massive cloud-covered atmosphere of Venus, including fundamental data about the formation of the planet.

The exploration of the giant outer planets began relatively recently. The Pioneer-10 and 11 flybys of Jupiter in 1973 and 1974 were followed by the Voyager-1 and 2 spacecraft. Voyager-1 encountered Jupiter in March 1979 and Saturn in November 1980. Voyager-2 flew by Jupiter in July 1979 and Saturn in August 1981. New data on these planets, their satellites and rings have revolutionized our concepts of the formation and evolution of the solar system. The Voyager-2 spacecraft is headed for an encounter with Uranus in 1986 that will provide our first look at this giant outer planet. Its trajectory will carry the spacecraft on to Neptune in 1989. The Pioneer-10 and 11 and Voyager-1 spacecraft are on trajectories leading out of the solar system, and they continue to return scientific data on the outer reaches of the solar system.

The Galileo mission will be launched to Jupiter in 1986 by the Space Shuttle/Centaur Upper Stage. The comprehensive science payload will extend our knowledge of Jupiter and its system of satellites well beyond the profound discoveries of the Voyager and Pioneer missions. During twenty months of operation in the Jovian system, Galileo will have the capability to provide as many as eleven targeted encounters with the Galilean satellites, and an instrumented probe will be injected into Jupiter's atmosphere.

The International Solar Polar Mission (ISPM) is a joint NASA and European Space Agency endeavor that will fly a package of experiments to investigate the Sun at high solar latitudes that cannot be studied from the Earth's position in the ecliptic. The ISPM spacecraft will be launched in 1986 on the Shuttle/Centaur Upper Stage.

The Venus Radar Mapper (VRM) mission, initiated in fiscal year 1984, will provide a global map of the cloud-shrouded surface of Venus. The VRM, using a synthetic aperture radar, will achieve a resolution sufficient to address fundamental questions regarding the origin and evolution of the planet, and will obtain altimetric and gravity data to determine accurately the gravity field, internal stresses, and density variations of the planet's interior. These data will be analyzed so that the evolutionary history of Venus can be compared with the Earth's. The VRM is scheduled for launch in 1988 on the Shuttle/Centaur Upper Stage.

A major new flight program element is a fiscal year 1985 new initiative in response to the Solar System Exploration Committee's recommendations. The Mars Geochemical/Climatology Orbiter (MGCO) will follow-up on the discoveries of Mariner 9 and Viking with emphasis on the geologic and climatic evolution of this complex planet. The MGCO mission will be a relatively low-cost mission due to the use of a modified Earth-orbiting spacecraft, thereby benefitting from industry's investment in development.

The Planetary Exploration program is founded on a coordinated research and analysis program. Research and analysis activities will continue to maximize the scientific return from ongoing and future missions, and from lunar sample and meteorite analysis, ground-based telescope observations, theoretical and laboratory studies, and instrument definition. This program strives for interdisciplinary coordination among various research groups to widely disseminate scientific results. A close coupling is maintained between the research programs and the planning activities that are undertaken to define the scientific rationale and technology needed for potential future missions.

### GALILEO DEVELOPMENT

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Spacecraft | $26,300,000 |
| Experiments | 8,100,000 |
| Ground operations | 21,700,000 |
| Total | 56,100,000 |

The objective of the Galileo program is to conduct a comprehensive exploration of Jupiter, its atmosphere, magnetosphere, and satellites through the use of both remote sensing by an orbiter and *in situ* measurements by an atmospheric probe. The scientific objectives of the mission are based on recommendations by the National Academy of Sciences to provide continuity, balance, and orderly progression of the exploration of the solar system.

The Orbiter and Probe will be launched together in 1986 as a single combined payload using the Shuttle/Centaur Upper Stage. Arrival at Jupiter will be in late 1988 when the Orbiter will provide remote sensing of the probe entry site and provide the link for relaying the probe data back to Earth. Twenty months of orbital operations will follow in which both Jupiter's surface and the dynamic magnetosphere will be comprehensively mapped. Eleven close flybys of Jupiter's major satellites are targeted.

The Galileo flight system will be powered by two general purpose heat-source redioisotope thermoelectric generators (RTG's) being developed by the Department of Energy. The Orbiter will carry approximately 100 kg of scientific instruments and the Probe will carry approximately 25 kg of scientific instruments.

During FY 1984, major activities of the Galileo program will involve completion of the Orbiter subsystems integration and testing, and the flight probe will be integrated with the Orbiter leading to environmental testing in FY 1985.

The FY 1985 funding will provide for completion of the environmental testing of the entire Galileo system; final subsystem and instrument calibration verification will be initiated; and development of the ground systems and the associated software required to support operation of the spacecraft will be continued. The FY 1985 funding is also required for hardware changes necessitated by recent information regarding the Jovian radiation and its potential effect on the Galileo spacecraft as currently designed; based on analysis of Voyager and Pioneer spacecraft data, heavy ion flux in the vicinity of the satellite Io may be more severe than previously

assumed. In addition, FY 1985 funds are required to reimburse the Department of Energy for the continued development of the radioisotope thermoelectric power generators for the Galileo mission.

## Venus Radar Mapper Mission

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Spacecraft | $65,800,000 |
| Experiments | 24,500,000 |
| Ground operations | 2,200,000 |
| Total | 92,500,000 |

The Venus Radar Mapper (VRM) project was initiated at the beginning of FY 1984. The mission objective is to address fundamental questions regarding the origin and evolution of Venus by obtaining global radar imagery of the planet. VRM will also obtain altimetric and gravity data to accurately determine the gravity field, internal stresses, and density variations of the planet's interior. The detailed surface morphology of Venus will be analyzed to compare the evolutionary history of Venus with that of the Earth.

The VRM spacecraft will carry a single major scientific instrument, a synthetic aperture radar, which will be used to obtain high resolution (0.5 to 1.0 km) images and altimetric data of the planetary surface. Gravity data will be obtained by processing radio signals from the spacecraft. The spacecraft will be developed by making extensive use of existing designs, technology, and residual hardware; for example, the spacecraft will use a bus structure, large antenna, and propulsion components from the Voyager program. Spare computers and other equipment will be obtained if available from the Galileo program after the Galileo launch in 1986.

In April 1988, the VRM spacecraft will be launched by the Shuttle/Centaur Upper Stage on a direct trajectory to Venus. Arriving at Venus in July 1988, the spacecraft will perform a retro-propulsive maneuver and enter a near-polar elliptical orbit; after an initial checkout period, the spacecraft will map the planet over a 243 day period (one Venus year).

During FY 1984, major effort on the Venus Radar Mapper program includes the initiation of the design and development activities on both the spacecraft and radar including and initiation of long-lead procurement items.

FY 1984 funds are required to complete the preliminary design reviews for the spacecraft and radar systems, to initiate fabrication of the subsystems, to initiate development of the mission software, and to complete the radar development model.

## International Solar Polar Mission

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Spacecraft | $4,000,000 |
| Experiments | 2,100,000 |
| Ground operations | 2,900,000 |
| Total | 9,000,000 |

The International Solar Polar Mission (ISPM) is a joint NASA and European Space Agency (ESA) program wherein ESA will provide the spacecraft and some scientific instrumentation, and the U.S. will provide the remaining scientific instrumentation, the launch, tracking support, and the radioisotope thermoelectric power generators. The mission is designed to obtain the first view of the solar system from outside the plane in which the planets orbit the Sun. The mission will study the relationship between the Sun and its magnetic field and particle emissions (solar wind and cosmic rays) as a function of solar latitude, to provide a better understanding of solar activity on the Earth's weather and climate. The ISPM will be launched in 1986 on the Shuttle/Centaur Upper Stage.

The ISPM was restructured in FY 1981, from a two-spacecraft mission—one provided by the United States and one provided by ESA—to a single ESA spacecraft mission; however, the United States participation in the program remains substantial. NASA is developing five of the nine principal investigator instruments, and three of the four European investigations have U.S. co-investigators. During FY 1983, the U.S. flight instruments were delivered to the ESA spacecraft developer for integration and system testing. All spacecraft testing has been completed and the spacecraft is being partially disassembled for storage until launch.

The FY 1985 funding is required to support U.S. principal investigators in their mission planning, and retrofitting of the U.S. instruments with the spacecraft prior to shipment to the Kennedy Space Center. In addition, FY 1985 funds are required to complete the ground system development activities and to reimburse DOE for the continued development of the radioisotope thermoelectric power generators.

### Mars Geoscience/Climatology Oribter (MGCO)

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Spacecraft | $6,000,000 |
| Experiments | 5,000,000 |
| Ground operations | 5,000,000 |
| Total | 16,000,000 |

The objective of the MGCO mission is to extend and complement the data acquired by the Mariner and Viking missions by mapping the global surface composition, topography, figure, gravity and magnetic fields of Mars to determine the location of volatile reservoirs and characterize their interaction with the Martian environment.

The MGCO mission, which is a FY 1985 new initiative, will be launched in 1990 with the Space Shuttle, and be inserted into Martian orbit in 1991, to perform geochemical, geophysical, and climatological mapping of the planet over a period of two years. The planning estimate for total cost of the development and mission operations is in the $300–375 million range. The project will be supported by approximately 48 direct personnel in FY 1985 and a total of 487 man-years over the life of the development activities.

The FY 1985 funds are required to initiate the Mars Geoscience/ Climatology Orbiter spacecraft design and development activities. An existing Earth-orbital spacecraft derivative will be selected for the MGCO mission based on the recommendation of the Solar System Exploration Committee to identify lower-cost Planetary Exploration missions. The scientific instruments will be selected based on a very focused scientific objective. The MGCO mission is the highest priority planetary exploration mission recommended by the Solar System Exploration Committee.

### Mission Operations and Data Analysis

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Voyager extended mission | $29,400,000 |
| Pioneer program | 7,000,000 |
| Planetary flight support | 22,400,000 |
| Total | 58,800,000 |

The objectives of the mission operations and data analysis activities are in-flight operation of planetary spacecraft and the analysis of data from these missions. Currently, two major classes of planetary spacecraft are operating—the Pioneer and the Voyager spacecraft. The planetary flight support activities are those associated with the design and development of planetary flight operations systems, and other activities that support the mission control, tracking, telemetry, and command functions for all planetary spacecraft.

Voyager 1 is now on a trajectory which will take it out of the solar system on a steep angle to the plane of the ecliptic; it will continue to collect data on the outer solar system environment while it also serves as a test bed for sequences and maneuvers to be used by Voyager 2 at Uranus and possibly Neptune. Voyager 2 is proceeding toward a January 1986 encounter with the planet Uranus. Unlike the other planets, the rotation axis of Uranus lies almost in the ecliptic so that its north pole now points at the Sun.

Operation of the Pioneer Venus and the Pioneer 6–11 spacecraft is continuing. The Pioneer Venus orbiter is measuring the dynamic character of the upper Venus ionosphere and its solar wind interaction which resembles that of a comet. The Pioneer 6–9 spacecraft are orbiting the Sun, and data is being acquired when unusual solar phenomena occur. The Pioneer 10 and 11 spacecraft are on a course that will take them out of the solar system in opposite directions while collecting data on the behavior of the diminishing solar wind. The search for gravitational evidence of a tenth planet will also be continued with these spacecraft.

Analysis of data from these missions continues to be rewarding. For example, analysis of the Voyager 1 data has led to the discovery of an oxygen-bearing molecule in the atmosphere of Saturn's satellite Titan, forcing a significant revision in photochemical models. Measurements made by the Mutch Memorial Station (Viking Lander 1) on Mars have provided new insight into the frequency of major dust storms and the transportation of fine soil particles around the landing site.

The planetary flight support activities include design, development and operation of the ground-based planetary navigation

system, the ground command and control system, the image processing system, and the ground data handling systems. In addition, the planetary flight support activities include the procurement, operation and maintenance of mission operations and general purpose scientific and engineering computing capabilities at the Jet Propulsion Laboratory.

During FY 1985, the operation and data analysis activities for the Voyager and Pioneer spacecraft will be continued. The FY 1985 planetary flight support funding is required for the continued preparation for the Galileo and ISPM missions and the Voyager 2 encounter with Uranus. The development of the multi-mission space flight operations center at the Jet Propulsion Laboratory will be continued in FY 1985 leading to a versatile control complex that will provide multi-mission data acquisition, telemetry and image processing, and commanding support capabilities for solar system exploration missions including Voyager, Galileo, ISPM, Venus Radar Mapper, MGCO, etc.

## Research and Analysis

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Supporting research and technology | $47,900,000 |
| Advanced programs | 9,000,000 |
| Mars data analysis | 4,300,000 |
| Halley's comet co-investigations and watch | 3,300,000 |
| Total | 64,500,000 |

The research and analysis program consists of four elements required to: assure that data and samples returned from flight missions are fully exploited; undertake complementary laboratory and theoretical efforts; define science rationale and develop required technology to undertake future planetary missions; and coordinate an International Halley's Comet Watch and provide co-investigator support to the European Space Agency's Giotto mission to Halley's Comet.

The supporting research and technology program element includes planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, and instrument definition.

The planetary astronomy activity includes all observations made by ground-based telescopes of solar system objects excluding the Sun. Emphasis is on the outermost planets, comets and asteroids. Observations are made at a wide range of wavelengths from ultraviolet to radio. The rate of new discoveries continues to be high, and the data acquired is used both for basic research in support of planetary program objectives and for direct support of specific flight missions. The planetary astronomy funding also provides for the continued operation of the Infrared Telescope Facility in Hawaii.

The planetary atmospheres activity includes data analysis, laboratory, and theoretical efforts. The properties of other planetary atmospheres are amenable to measurement with planetary spacecraft and can aid us in better understanding our own weather and climate. Observations of the atmospheres of Venus, Jupiter and

Saturn, acquired by Pioneer Venus and Voyager, have laid the basic observational groundwork for major advances in this field.

The planetary geology/geophysics activity is a broadly scoped program that includes the study of surface processes, structure, and history of solid components (including rings) of the solar system and investigation of the interior properties and processes of all solar system bodies, both solid and gaseous. This program emphasizes comparative studies to gain a fundamental understanding of the physical processes and laws which control the development and evolution of all planetary bodies, including the Earth. In this respect, data from the Venus Radar Mapper mission will be of crucial importance.

The planetary materials/geochemistry activity supports an active scientific effort to determine the chemistry, mineral composition, age, physical properties and other characteristics of solid material in the solar system through the study of returned lunar samples and meteorites and through laboratory and theoretical studies of appropriate geochemical problems. Extraterrestial dust grains, collected for analysis, continue to yield new and otherwise unobtainable information about the solar system, and its early history. This program is coordinated with the lunar sample and meteorite research which is supported by other agencies such as the National Science Foundation. The operation of the Lunar Curatorial Facility is also supported by the planetary materials/geochemcial funding.

The instrument development and definition activity is directed toward ensuring maximum scientific return from future missions by the definition and development of state-of-the-art scientific instrumentation which is optimized for such missions.

The objective of the advanced program activity is to provide planning and preparation for the systematic exploration of the solar system on a scientifically and technically sound basis. Prospective planetary missions are identified and defined through long-range studies; their technological and fiscal feasibility is evaluated, and their scientific merit is determined through interaction with the scientific community. The strategy for future solar system exploration has been developed by the Solar System Exploration Committee (SSEC), an advisory group, which has recommended a program of "low-cost" but scientifically important potential future missions, together with occasional more ambitious, larger scope missions.

The Mars Data Analysis activity continues to ensure that we capitalize on the wealth of data provided by Viking and earlier missions and that we are scientifically prepared for the next phase of Mars exploration, more specifically, the Mars Geoscience/Climatology Orbiter mission. While continuing to support a variety of scientific investigations, the major emphasis of this program will address the origin and evolution of Martian volatiles.

The International Halley's Comet Co-Investigations and Watch will capitalize on the opportunity to observe Comet Halley during its next apparition in 1985–1986 by supporting co-investigators on the European Space Agency (ESA) Giotto mission, and by conducting complementary remote sensing investigations using both Earth-orbiting and ground-based facilities. The ESA Giotto mission will

fly by Halley's Comet in 1986. Concurrently, an observation program called the International Halley Watch, coordinated by the United States, will conduct world-wide scientific observations of the Comet Halley. The objectives of the Watch are to: (1) coordinate scientific observations of Comet Halley through its 1985–1986 apparition; (2) promote the use of standardized instrumentation and observing techniques; (3) help insure that data is properly documented and archived; and (4) receive and distribute data to participating scientists.

During FY 1985, research efforts will continue in the areas of planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, Mars data analysis, and in the development of required technology to undertake future missions. Telescope observations will provide data complementary to that obtained from the flight missions, with emphasis on the outermost planets, comets and asteroids. A variety of efforts will be pursued to improve our understanding of planetary atmospheres, including laboratory studies of reactions in deep planetary and tenuous cometary atmospheres. Geology/geophysics research will be directed, in FY 1985, at specific problems in understanding the various processes that have shaped planetary surfaces, as well as geological analyses and a cartography effort based on the Galilean and Saturnian satellite imaging data acquired by Voyager. Analysis of lunar samples, meteorites, and extraterrestrial dust particles will be continued in FY 1985 to determine their chemical and physical properties and thereby derive their origin and evolutionary history. Instrument definition for potential future missions will also be continued.

The FY 1985 Halley's Comet Co-Investigations and Watch funding is required to support U.S. co-investigators involved in the European Space Agency's Giotto mission, and to provide support for a Jet Propulsion Laboratory managment team and several scientists at other institutions, who are establishing a worldwide network for the astronomical study of Halley's Comet.

In addition, the FY 1985 funding is required to continue to operate both the Infrared Telescope Facility and the Lunar Curatorial Facility.

### 6. SPACE APPLICATIONS, $384,100,000

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Solid Earth observations program | $63,600,000 |
| Environmental observations program | 220,700,000 |
| Materials processing in space program | 23,000,000 |
| Communications program | 60,600,000 |
| Information systems program | 16,200,000 |
| Total | 384,100,000 |

### Solid Earth Observations Program

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Landsat-4 | ..... |
| Shuttle/Space payloads | $18,100,000 |
| Geodynamics | 29,900,000 |
| Research and analysis | 15,600,000 |
| Technology transfer | ..... |
| Total | 63,600,000 |

The objectives of the Solid Earth Observations program are to develop space observations and experimentation techniques to further the understanding of the global, physical, chemical, and biological processes involving the land areas of the Earth and interactions of the land areas with the Earth's oceans and atmosphere; to improve our ability to systematically evaluate the composition and geometry of the Earth's mineral and energy resources; and to increase our understanding of the Earth, its interior structure and composition, its rotational dynamics, the processes related to the movement and deformation of its crust, and mechanisms associated with the occurrence of earthquakes.

Principal elements of the program include the development of spaceborne and supporting ground systems; improved data processing and analysis techniques; sensor and technique development; as well as basic and applied research for identifying, monitoring, analyzing and modeling the vegetated and geological features of the Earth.

Another important aspect of the Solid Earth Observations program is the research associated with understanding the physical relationship of electromagnetically sensed phenomena to the radiation emitted or reflected by various types of surface features of the Earth; the development of models to increase our understanding of global processes; and the evaulation of the use of space-derived data along with other data sources in meeting the research needs of the scientific community.

Studies of the movement and deformation of the Earth's crust, the rotational dynamics of the Earth, and the Earth's gravity and magnetic fields provide information which is needed to: understand the processes leading to the release of crustal strain in the form of earthquakes; improve our understanding of the formation of mineral deposits; contribute to long-term weather and climate forecasting; and better understand the Earth as a planet. Space techniques such as laser ranging to satellites and the Moon, and very long baseline interferometry using radio stars or satellites, are the only methods which can provide the precise measurements needed for these studies.

Landsat-4, launched on July 16, 1982, has continued to provide Multispectral Scanner and Thematic Mapper images for many applications in civil remote sensing. NOAA assumed operational responsibility for the Landsat-4 spacecraft and the Multispectral Scanner in January 1983. NASA will retain responsibility for the Thematic Mapper operations and data processing through FY 1984. The Landsat-5 spacecraft has been removed from storage, modified to correct for anomalies developed inorbit with Landsat-4, and launched on March 1, 1984.

The objective of the Shuttle/Spacelab payload development project is to develop, test, and evaluate Earth-viewing remote sensing instruments and systems to obtain data for solid earth observations research. Both the Shuttle Imaging Radar, which was flown on the Shuttle orbital test flight in November 1981 to evaluate the utility of spaceborne imaging radar for geologic exploration, and

the Shuttle Multispectral Infrared Radiometer which was used to determine the optimum spectral bands for surface materials classification, operated successfully. The Large Format Camera, required for high resolution mapping applications, is being prepared for launch on the Shuttle in 1984. The next generation Shuttle Imaging Radar is also under development leading to a 1984 Shuttle launch.

The Multispectral Linear Array (MLA) advanced technology development activities are being focused on the development of a future high performance MLA instrument which can be used as a diagnostic tool for fundamental research in remote sensing. The MLA solid-state sensor has a number of significant features such as electronic scan, inherent geometric and spectral registration, and programmable high spatial and spectral resolution. The critical technology development and supporting research on the linear array instrument and the Shuttle Imaging Spectrometer is being continued in FY 1985.

Along with the Environmental Observations program, the Solid Earth Observations activities compose an integral part of NASA's total Earth sciences and applications effort with emphasis on understanding the Earth as a planet, studying its dynamics, processes, habitability, and solar-terrestrial environment.

*Landsat-4*

The objective of the Landsat-4 program was to develop, launch, and operate an advanced land observing system, and to assess and demonstrate the utility of satellite-based Earth resources remote sensing systems with the new experimental Thematic Mapper (TM) and the flight-proven Multispectral Scanner (MSS). Landsat-4 was successfully launched in July 1982. The Landsat-4 backup spacecraft (Landsat-D prime) will be launched in 1984. The major technical focus of the Landsat-4 program involved a test of the Thematic Mapper's capabilities and an improved ground data handling system. The Thematic Mapper offers higher resolving power and greater spectral coverage than previous instruments. These advantages promise to open up a significant number of new uses of Landsat data and enhance many current uses.

The National Oceanic and Atomospheric Administration (NOAA) assumed control of Landsat-4 operations in January 1983. NASA will retain responsibility for operation of the TM and associate data processing until it becomes fully operational in January 1985. The Landsat-5 spacecraft has been removed from storage, modified to correct anomalies developed in-orbit with Landsat-4, and launched March 1, 1984. NASA is currently conducting a study to determine if the Landsat-4 spacecraft should be placed into a lower orbit after Landsat-5 becomes operational so that it may be available for a possible future retrieval by the Space Shuttle.

There is no requirement for FY 1985 funds as the responsibility will be transferred to NOAA.

*Shuttle/Spacelab payload development*

The objective of this project is to develop, test, and evaluate Earth-viewing remote instruments and systems to obtain data for land remote sensing research.

In FY 1984, preparations are continuing for the flights of the Large Format Camera (LFC) and the Shuttle Imaging Radar-B (SIR-B). The Large Format Camera is required for high resolution mapping applications. The new attitude reference system for the LFC has been completed, and the launch of the LFC is scheduled for 1984. The SIR-B will obtain a quantitative assessment of the effect of various radar viewing geometries on the mapping of surface texture and topographic features. The SIR-B instrumentation is based on an upgraded SIR-A instrument including the addition of a variable look-angle antenna, digital data handling, and increased bandwidth and resolution. Data will be recorded on board and transmitted via the Tracking and Data Relay Satellite System (TDRSS).

The focus of the Multispectral Linear Array (MLA) technology development is on a future high performance MLA instrument for use as a diagnostic tool utilizing the Space Shuttle for fundamental research in remote sensing and the development of advanced spectrometer technology. The MLA class of solid state sensors has a number of significant features, such as electronic scan, inherent geometric and spectral registration, and programmable high spatial and spectral resolution.

FY 1985 funding is required for operation of the Large Format Camera and the Shuttle Imaging Radar-B (SIR-B) plus data analysis. FY 1985 funding is also required for continued development of the Multispectral Linear Array experimental instrument.

*Geodynamics*

The objective of the Geodynamics program is to increase our understanding of the solid Earth by studying the movement and deformation of its tectonic plates; its rotational dynamics, and its internal dynamics and structure. The program uses space techniques for precise positioning to determine how the plates are moving; how crustal strain is accumulated and released at plate boundaries; and how the Earth's polar motion and rotational rate interact with variations of mass distributions in the Earth's atmosphere, oceans, core and mantle. Models of the Earth's global gravity and magnetic fields are developed in order to improve our understanding of the structure and dynamics of the Earth and to aid in studies of large scale ocean circulation. Over the long term, geodynamics research will also contribute to our understanding of earthquake mechanisms, the geophysical processes associated with the formation of petroleum and mineral deposits, and help to gain a clearer understanding of the form and extent of mantle convection and the origin of the Earth's magnetic field.

The plate motion and regional crustal deformation measurements (in the western U.S., Alaska, Mexico, and South America) will be continued in FY 1985. The Pacific Plate motion experiments with Japan will be repeated and studies will be initiated in the Mediterranean with some European countries and in the Caribbean. Operation of the Laser Network will also be continued in FY 1985. In addition, theoretical studies of crustal motion and internal core dynamics, and modeling and interpretation of geopotential fields will be continued in FY 1985.

In FY 1985, the Crustal Dynamics Project will continue the development of laser ranging and microwave interferometric systems and, in cooperation with 16 other countries, will be acquiring data on the contemporary movement of most of the major tectonic plates.

Acquisition and processing of laser data for sites in the United States, the Pacific, South America, and Australia will be continued in FY 1985. In addition, the Laser Geodynamics Satellite (LAGEOS) will continue to be used for studies of plate motion. This data is being used to improve gravity field models and has recently detected changes in the Earth's gravity field. Under a tentative agreement with Italy, a joint program is being planned for a second LAGEOS mission wherein the mission will be developed by Italy and launched by the U.S.

*Research and analysis*

The major objective of the Solid Earth Observations Research and Analysis program are to develop remote sensing technology and to apply such technology to the study of the Earth's land surface.

Sensor system technology currently under development is needed to obtain measurements of Earth radiation in various portions of the electromagnetic spectrum. Typical questions encountered in this type of research concern the precision that can be achieved with specific techniques and tradeoffs involved when using specific sensor systems. Research is also conducted to develop procedures for extracting information about the Earth's surface from remotely sensed data. This type of research is concerned with such topics as pattern recognition; image segmentation and classification; modeling of scene components; atmospheric effects in remotely sensed imagery; data base manipulation and merging; etc. This wide range of technique development activities is designed to provide a new set of unique tools for Earth related research of both a basic and applied nature.

The Research and Analysis program also involves the application of remote sensing methods to the study of the Earth. Research is typically conducted within specific disciplinary fields to determine the various types of ecological, geological, and hydrological information that can potentially be inferred from remotely sensed data. Global Earth phenomena currently under study include the influence of vegetation upon the global carbon dioxide budget and other biogeochemical cycles, and rock weathering in arid regions. A wide range of topical problems have tentatively been identified as likely candidates for future research studies on an interdisciplinary nature.

In ecology and hydrology, the focus in on understanding how land processes, most of which are mediated by vegetation, interact with global processes relating to climate, the hydrological cycle, and the various biogeochemical cycles. The principal satellite sensors employed are the Thematic Mapper, the Landsat Multispectral Scanner, and the Advanced Very High Resolution Radiometer; but significant inputs are also expected from other sensors such as the Shuttle Imaging Radar. In geology, research is underway to evaluate the utility of different remote sensing techniques for geological

mapping, and to apply techniques of proven utility to the study of the Earth's crust. These basic crustal studies are expected to lead to an improved understanding of the physical processes responsible for the concentration of geological resources within the Earth's crust.

In addition, feasibility and conceptual design studies of future sensors and missions are being conducted to ensure future capabilities in remote sensing of Earth resources.

Select remote sensing projects are jointly conducted with outside cooperating organizations to apply remote sensing technology in a problem-oriented setting. Joint research projects will continue to be carried out with public and private sector organizations involving predictive permafrost modeling in the Alaskan Arctic biomes; wetlands stratification for biogeochemical cycle modeling; assessment of vegetative stress from acid rain; crop condition assessment and monitoring; cropland conversion; timber resource inventory; facility site selection and waste disposal impact assessment; and land capability analysis. In addition, nine multi-disciplinary, university-based remote sensing centers will be maintained for the purpose of research, test, and evaluation of emerging remote sensing techniques.

During FY 1985, the research and analysis disciplines will make use of the data from Landsat-5 Thematic Mapper. New radar data from the SIR-B will also be used to conduct further research. The FY 1985 Research and Analysis program will focus on the analysis of this new data to improve our understandings of long-term land processes, and develop some techniques for merging multisensor/multispectral data sets. Fundamental remote sensing science research on scene radiation and atmospheric effects will be continued, as will pattern recognition and image analysis. Advanced mission studies will be continued with emphasis on Shuttle-borne sensor feasibility and space platform payloads.

Investigation are being conducted in FY 1985 to extend our basic understanding of sensor-target relationships in the optical, thermal, and microwave portions of the spectrum. Results to date indicate microwave measurements can be used to model vegetation canopies according to leaf, branch, and trunk components. This research also supports generic technique development to extract the full potential of information found in the image data; results to date include a technique which can be used to identify spatially-related spectral patterns in image data which improves discrimination, for instance, between forested and agricultural fields, as well as between different densities of forest canopy.

*Technology transfer*

The technology transfer program provides for the development, experimental test and evaluation, and transfer of remote sensing technology applications for operational use by public and private organizations.

User requirements and supporting activities have maintained communications at the national level between NASA and the user community to determine and analyze national priorities and user needs, inform users of existing and planned technological capabilities, obtain external evaluations of technology transfer programs

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for planning purposes, and develop program awareness and technical capabilities in educational institutions. Cooperative efforts have been conducted with state and local governments to evaluate proven Landsat applications in natural resource and environmental management.

Fiscal year 1984 funding was used to continue these important activities which encourage the transfer of remote sensing technology to public and private organizations.

There is no funding for fiscal year 1985.

## Environmental Observations Program

### FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Upper atmosphere research and analysis | $31,000,000 |
| Atmospheric dynamics and radiation research and analysis | 28,500,000 |
| Oceanic processes research and analysis | 19,400,000 |
| Space physics/research and analysis | 21,700,000 |
| Shuttle/Spacelab payload development | 7,800,000 |
| Operational satellite improvement program | |
| Earth radiation budget experiment | 8,100,000 |
| Extended mission operations | 29,500,000 |
| Upper atmosphere research satellite experiments and mission definition | 55,700,000 |
| Interdisciplinary research and analysis | 1,000,000 |
| Tethered satellite payloads | 3,000,000 |
| Scatterometer | 15,000,000 |
| Total | 220,700,000 |

The objectives of the Environmental Observations program are to improve our understanding of the processes in the magnetosphere, atmosphere, and the oceans; to provide space observations of parameters involved in these processes; and to extend the national capabilities to predict environmental phenomena, both short and long term, and their interaction with human activities. Because many of these phenomena are global or regional, they can be most effectively, and sometimes solely, observed from space. NASA's program includes scientific research efforts plus the development of new technology for global and synoptic measurements. NASA's research satellites provide a unique view of the radiative, chemical, plasma acceleration, and dynamic processes occurring in the magnetosphere, atmosphere, and oceans.

To achieve these goals, a number of significant objectives have been established for the next decade. These include advancing the understanding of the upper atmosphere through the determination of the spatial and temporal distribution of ozone and select nitrogen, hydrogen, and chlorine species in the upper atmosphere and their sources in the lower atmosphere; optimization of the use of space-derived measurements in understanding large scale weather patterns; advances in our knowledge of severe storms and forecasting capabilities, ocean productivity, circulation, and air-sea interactions; an improved knowledge of seasonal climate variability leading to a long-term strategy for climate observation and prediction; and a comprehensive understanding of solar terrestrial processes and a detailed determination of the physics and coupling between the solar wind, magnetosphere, and ionosphere.

Effective utilization of remote sensing requires a balanced set of activities including: analytical modeling and simulation, laboratory research of fundamental processes, development of instrumentation, flight of the instruments on the Space Shuttle and dedicated spacecraft, collection of in situ ancillary or validation data, and scientific analysis of data. The approach is to develop a technological capability with a strong scientific base and then to collect appropriate data, through remote and in situ means, which will address specific program objectives.

Studies of the upper atmosphere have led to a new asssesment of the impact of chlorofluorocarbons on stratospheric ozone, and a report is being forward to the Congress in January 1984. The revised assessment of the predicted impact is somewhat less severe; this assessment is the result of improved precision in our continuing program of laboratory chemical kinetics measurements.

Three-dimensional models of the stratosphere are being developed to quantify our understanding of the interrelation of chemistry with dynamics and radiation. The record of satellite ozone measurements now extends for over a decade and is being used in studies to determine if there have been long term trends in the average amount of global ozone which shields the Earth's surface from harmful ultraviolet radiation.

The Upper Atmospheric Research Satellite (UARS) will place a set of instruments in Earth orbit which will make a comprehensive measurement of the state of the stratosphere, providing data about the Earth's upper atmosphere in spatial and temporal dimensions which are presently unattainable. Detailed definition studies of the instruments have been completed, and the design and development activities have begun. In FY 1985, design and development activities will be initiated on the UARS observatory.

The development of the Earth Radiation Budget Experiment (ERBE) and the Solar Backscatter Ultraviolet instrument development is proceeding on schedule toward a 1984 launch. NASA is also continuing to support the National Oceanic and Atmospheric Administration (NOAA) by managing the implementation of the NOAA and Geostationary Operational Environmental Satellites (GOES) series on a reimbursable basis. Preparations are proceeding to launch NOAA-F in 1984.

Design and development activities will be initiated on a Scatterometer, which will be flown on the Navy Remote Ocean Sensing System (N-ROSS), in late 1988 to acquire global ocean data.

The ability to perform temperature and moisture soundings of the atmosphere from geostationary orbit has been demonstrated by the flight of the NASA-developed visible/infrared spin-scan radiometer and atmospheric sounder instrument on the GOES spacecraft. The opportunity afforded by geostationary orbits to observe a localized region continuously will permit intensive study of the evolving temperature and moisture environment of severe local storms. Low earth-orbit sounding capabilities are now enabling the extension of forecast reliability from three to five days. In certain situations, reliable forecasts of eight to ten days duration have been achieved.

Virtually all of the data from the Seasat mission has been archived and much of the Nimbus-7 ocean data has been analyzed. This information is being used to define potential low cost ap-

proaches to the use of demonstrated ocean observing techniques to address a variety of ocean research challenges.

The Nimbus spacecraft continue to collect unique data sets to aid in the study of long term trends of the Earth's atmosphere, oceans and polar ice. The Solar Mesosphere Explorer (SME) data collection over the last year has made a major contribution to the study of the El Chichon volcano. The Dynamics Explorer–1 continues to collect valuable data on magnetosphere-ionosphere coupling processes. In addition, the ISEE–3 spacecraft, renamed International Cometary Explorer, has completed an exploration of the Earth's geomagnetic tail and is being redirected toward the planned encounter in 1985 with the comet Giacobini-Zinner.

Along with the Solid Earth Observations program, the Environmental Observations activities compose an integral part of NASA's total Earth sciences and applications effort with emphasis on understanding the Earth as a planet, studying its dynamics, processes, habitability, and solar-terrestrial environment.

*Upper atmosphere research and analysis*

The upper atmosphere research program is a comprehensive research and technology effort designed to investigate and monitor the phenomena of the upper atmosphere and related phenomena in the lower atmosphere. It is aimed at improving our basic scientific understanding of the global atmosphere and the methods needed to assess its susceptibility to significant chemical and physical change. The program's three major thrusts are in the areas of upper atmospheric research, stratospheric air quality research and tropospheric air quality research.

In particular, the goal of the upper atmosphere research program is to understand the physics, chemistry and transport processes in the atmosphere on a global scale, and to assess as accurately as possible the perturbations to the atmosphere caused by man's activities. In order to accomplish this, efforts are underway to: (1) improve upper atmosphere and global troposphere models, validate them, and assess their uncertainties; (2) measure important trace chemical constituents, temperature, and radiation fields throughout the atmosphere; (3) develop sensors capable of making chemical and physical measurements of the upper atmosphere and the global troposphere both directly and remotely from space; (4) assemble and maintain the existing long-term data base of stratospheric and troposphereic ozone measurements to aid in the detection of long-timescale natural variations and man-made ozone changes; (5) determine the effects of global tropospheric chemistry on the atmosphere; (6) conduct theoretical and field studies of tropospheric/stratospheric exchange; and (7) carry out laboratory kinetics and spectroscopy investigations to support these activities.

A variety of *in situ* and remote sensing techniques are needed to meet the objectives of determining and understanding the distribution of ozone and other trace species in the atmosphere. Data sets from satellites are now generally available to the scientific community including a record of the global distribution of ozone extending back over a decade, and simultaneous observations of a number of trace constituents for the winter of 1978–79. This data is being exploited to determine if trends in the ozone amount have been de-

tected and to understand those processes which are directly involved with these trends. A new assessment of the state of the upper atmosphere and its susceptibility to change has been prepared and delivered to Congress and the Environmental Protection Agency in January 1984. This assessment predicts smaller changes in the future level of ozone due to emissions of chlorofluorcarbons.

The most recent assessment of changes in the ozone layer has uncovered more diversity in the model predictions than expected, plus the combined effect caused by the addition of several gases to the atmosphere; thus additional study is required. During FY 1985 model calculations and interpretation of satellite data will be used to try to resolve as many of these questions as possible. The development of more realistic two- and three- dimensional models will be continued. The global data sets from past and current satellites will be further analyzed to help understand large-scale processes at work in the upper atmosphere and the distribution of tropospheric carbon monoxide.

The intercomparison of balloon, aircraft, and ground-based measurements will be continued to ensure the validity of the different techniques that have been developed and to observe chemical species in the stratosphere and troposphere to determine the exchange of gases between the lower and upper atmosphere. These balloon and aircraft measurement programs are the only way to measure many of the localized phenomena of the atmosphere; they also help to validate satellite observations. Studies of potential new instruments for use on future satellites and suborbitral measurement platforms will be conducted to ensure that new technologies are put to use in improving the capability and cost efficiency of tropospheric composition and upper atmosphere measurements.

*Atmospheric dynamics and radiation research and analysis*

The research and analysis activities within the Atmospheric Dynamics and Radiation program comprise a core effort which is fundamental to using space technology to solve problems in atmospheric science. The program's three main thrusts are in the areas of global-scale processes research, mesoscale processes research and climate research.

The objectives of the global scale research program are to improve our understanding of large-scale atmospheric behavior and to develop improved capability to observe the atmosphere from space; the program involves the development of advanced remote sensing instrumentation to observe the atmosphere, the development of advanced analysis techniques to better utilize existing meteorological satellite data, and development of advanced numerical models which use satellite observations to describe the state of the atmosphere both diagnostically and predictively. Recent accomplishments include the development of techniques which utilized passive multispectral data from the NOAA operational satellites to provide global maps of a number of key atmospheric and surface parameters. In addition, special attention has been devoted to developing active lidar techniques to provide detailed profiles of atmospheric temperature, pressure, and moisture data from spaceborne platforms. Simulations of these advanced techniques indicate a great potential in meteorological predication capability.

The objectives of the mesoscale processes research program are to improve our understanding of the behavior of the atmosphere on short (minutes to hours) time scales and over local to regional size scales (severe weather, such as tornadoes and hurricanes). Since the characteristic parameters of these mesoscale processes cannot be measured directly, new techniques are under study to derive the information from other observations which can be directly measured. Such an activity requires advanced data handling and analysis techniques which rely upon man-computer interactive display and manipulation. A joint NASA–NOAA project of this type was completed and is known as the Centralized Storm Information System. In the area of remote sensor development, successful flights of instrumentation on the ER–2 aircraft to observe cloud top dynamics have been completed, and a feasibility study of a potential lightning mapper has been completed.

The Climate Research Program seeks to develop a space capability for global observations of climate parameters which will contribute to our understanding of the processes that influence climate and its predictability. Research is focused in accordance with the National Climate Program wherein NASA has the role of lead agency for solar and earth radiation research. Future study thrusts will be aligned with programs of solar irradiance monitoring, earth radiation budget monitoring and analysis, the distribution and effect of cloud systems and stratospheric aerosols on the radiation budget, and selected process studies which relate to monitoring of climate change. The past year's activities have included extensive flight surveys to monitor the effect of the El Chichon volcanic aerosols on the climate, successful launch of the International Satellite Cloud Climatology Project (ISCCP), development of the First ISCCP Regional Experiment (FIRE), publication of an extensive Antarctic Sea Ice Atlas, and continuing support for solar irradiance monitoring activities through the flight of active cavity radiometers on Spacelab 1.

FY 1985 funding is required to conduct aircraft flights to study the detail of flows around thunderstorms and fronts, continue comparison of models, study atmospheric scale interactions, and develop techniques to display model outputs in 3-dimensions. Other activities will involve continued retrieval and archiving of global International Satellite Cloud Climatology Project data sets, analysis of data from the Earth Radiation Budget Experiment and the Stratospheric Aerosol and Gas Experiment, and continued ground based and rocket flight support for solar irradiance monitoring. Technology development of active temperature, pressure, and moisture sounders as well as basic lidar technology development will also be continued in FY 1985.

*Oceanic processes research and analysis*

The Oceanic Processes Research and Analysis program emphasizes the development and application of spaceborne observing techniques to advance our understanding of the fundamental behavior of the oceans, as well as to assist users with the implementation of operational systems. As such, the program operates in concert with a variety of federal agencies (Defense, NOAA, NSF) and foreign countries (Canada, Europe, Japan).

The analysis of Seasat data has demonstrated the technical feasibility of utilizing satellite altimetry data to determine the surface topography of the ocean, from which surface currents can be estimated, and scatterometry data to determine the surface roughness of the ocean, from which surface winds can be estimated. Definition of global ocean altimeter and scatterometer technology are key elements in such an effort. NASA is currently reviewing the possibility of combining these activities with the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean/Global Atmosphere (TOGA) program, two international ocean-related activities being planned under the auspices of the World Climate Research Program, to study global ocean circulation.

An analysis of Coastal Zone Color Scanner data from Nimbus-7 has demonstrated the feasibility of utilizing satellite color scanners to determine near-surface chlorophyll concentrations. In addition to real-time cruise planning, this imagery can be used to quantitatively relate variations in biological activity to variations in the surrounding physical environment.

Recent analysis has also demonstrated the feasibility of both active and passive satellite microwave systems for determining characteristics of sea ice cover. For example, NASA plans to use data from the future microwave radiometer aboard the Defense Meteorological Satellite to estimate global sea ice cover, and to use the synthetic aperture radar aboard the European Space Agency's ERS–1 spacecraft to estimate detailed changes in the ice pack. Ultimately, this data will be used to try to relate how the circulation of the oceans and their sea ice cover mutually respond to changes in atmospheric forcing, how primary productivity responds to changes in nutrient distributions as affected by ocean currents, and how the oceans themselves affect our climate.

During FY 1985, analyses of both Nimbus-7 and Seasat data will be continued. Work will also be continued on the pilot ocean data system with major thrusts being focused on planning a data processing and archival facility for the Scatterometer which is being flown on the Navy's N–ROSS mission, and the future TOPEX mission. Additionally, archival facilities will be established, in concert with NOAA, for sea ice data derived from the Defense Meteorological Satellite Program/Special Sensor for Microwave Imaging.

FY 1985 funds are also required to continue the definition of observational capabilities to advance our understanding of fundamental ocean behavior. For example, definition of the Ocean Topography Experiment (TOPEX), which will employ an altimeter to acquire information on global sea surface height, which is needed to determine ocean circulation, will be continued during FY 1985. These studies will be directed toward refining the design, performance, and cost of the proposed TOPEX program. In particular, satellite definition studies with industry, initiated in FY 1984, will be continued, as will breadboarding of the critical technology areas.

*Space physics research and analysis*

The space physics research and analysis program is a broadly structured effort to enhance our understanding of the characteristics and behavior of plasmas in the solar corona, the interplanetary medium and in the vicinity of the Earth and other planets. These

studies include: the complex coupling of the atmosphere with the ionosphere and the magnetosphere; the solar wind and how it interacts with planetary megnetospheres and ionospheres; and how variations in the solar wind are coupled into the near planetary environment and neutral atmosphere. This discipline also includes the conduct of active experiments to extract information under controlled conditions and the use of space as a laboratory for the study of plasmas in parameter regimes that are unattainable on the Earth. The understanding of the plasmas in the solar system, the only naturally occurring plasmas to which we have direct access, will also enable us to refine theories regarding astrophysical plasma processes.

The major thrust of the space physics program is directed at studies of the near Earth environment, from the flow of solar wind past the magnetosphere to manifestations of variations of the plasma environment detectable near the surface of the Earth. Not only are these studies of great interest to the Earth sciences community, but also there are other practical components concerned with these aspects, such as ionospheric influences on communication, global circulation of the atmosphere driven by magnetospheric input, the charging of spacecraft immersed in plasma, and the behavior of antennas and their signals in the magnetosphere.

The field of research is one of relative maturity, with emphasis on multipoint and time sequence measurements and on active perturbation experiments rather than isolated exploratory observations. For example, there are presently three spacecraft systems—the Interplanetary Monitoring Platform, the International Sun-Earth Explorer (ISEE) and the Dynamics Explorer taking such measurements. In addition, the Active Magnetospheric Particle Tracer Explorer (AMPTE), which is scheduled for launch in 1984, will be releasing tracer plasmas and making space and time measurements. There is an active program of sounding rocket and balloon investigations aimed principally at spatially or temporally isolated atmospheric, ionospheric or magnetospheric phenomena. An active theoretical and modeling program and a small supporting laboratory program are also being conducted.

The solar terrestrial theory program continues to provide a strong basis for all of the programs in both solar physics and space plasma physics. Theoretical groups are engaged in research on virtually every aspect of the solar terrestrial problem by using both fundamental process calculations and numerical models of the large scale phenomena.

During FY 1985, NASA will continue its program of suborbital investigations, theoretical and laboratory studies, and analyses of existing data from spacecraft. Particular emphasis will be placed on the analysis of data from ISEE–3, which has spent most of 1983 in the Earth's magnetotail. It is being redirected to encounter the comet Giacobini-Zinner in 1985 (ISEE–3 was recently renamed to be the International Cometary Explorer). Definition studies will be contained during FY 1985 on such missions as the potential cooperative European Origin of Plasmas in Earth's Neighborhood mission, which will be renamed the International Solar-Terrestrial Physics Mission and on Shuttle/Spacelab missions such as the Space Plasma Lab and chemical release investigations for support

to the DOD Combined Chemical Release and Radiation Effects Satellite (CRRES).

The solar terrestrial theory program will be continued during FY 1985 to research the full range of phenomena in this portion of the environment. Steps will be taken to build a comprehensive and quantitative aggregate model of the solar terrestrial interaction.

*Shuttle/Spacelab payload development (environmental observations)*

The Space Transportation System offers the unique opportunity for frequent short-duration flights of instruments. The Environmental Observations program has incorporated this capability into the Shuttle/Spacelab payload development activities in these important aspects: early test, checkout and design of remote sensing instruments for long duration free-flying missions; and short-term atmospheric and environmental data gathering for basic research and analysis where long-term observations are impractical.

The Measurement of Air Pollution from Satellite (MAPS) experiment is a gas-filter correlation radiometer designed to measure the levels of tropospheric carbon monoxide and the extent of interhemispheric mass transport in the lower atmosphere. The instrument was flown successfully on the Shuttle orbital flight test in November 1981. The instrument performed successfully and obtained approximately 40 hours of data on the global distribution of carbon monoxide in the atmosphere. The MAPS experiment has been approved for a series of reflights on OSTA-3, currently scheduled for launch in 1984; and OSTA-5 and OSTA-7 scheduled for launch in 1986 and 1987, respectively. In addition, to provide data on seasonal variations of carbon monoxide, a flight of MAPS on ECOM-1 (Environmental Observations Mission) in mid-1985 is being considered.

The objective of the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS) experiment is to make detailed measurements of gaseous constituents (e.g., hydrogen chloride, water, ammonia, methane) in the Earth's atmosphere by using the technique of infrared absorption spectroscopy. The data will help determine the compositional structure of the upper atmosphere, including the ozone layer and its spatial variability on a global scale. The instrument is scheduled for launch in 1984 on Spacelab-3.

In response to an Announcement of Opportunity, a number of principal investigator class instruments were selected for development and flight as part of the Shuttle/Spacelab payload program. Payloads under development include Active Cavity Radiometer-I (ACR-1) which is designed to aid in the study of the Earth's climate and the physical behavior of the Sun. A reflight of ACR-1 is currently under review. Other experiments have also been selected for reflight, including some instruments which were flown on the Shuttle orbital flight tests and on Spacelab-1.

FY 1985 funds will be used to support the Measurement of Air Pollution from Satellites (MAPS) science team activities including data reduction, refurbishment for reflight and upgrading of the ground service equipment and new data recorder.

The initial flight of the Atmospheric Tracer Molecules Observed by Spectroscopy (ATMOS) instrument is scheduled for 1984. The FY 1985 funding is required to support the continued science team

activities, data processing and analysis of the data, and refurbishment reflight in 1986.

FY 1985 funding is also required to continue the Active Cavity Radiometer (ACR) data processing, science team activities, and refurbishment for reflight on a future Shuttle mission. Definition studies of a potential free-flyer version of ACR will also be undertaken. The principal investigator instrument development and reflight program will be continued in FY 1985 with research efforts concentrated on atmospheric chemistry, solar intensity and variability, and upper atmospheric winds.

During FY 1985, preliminary definition and breadboard laboratory activities will be conducted on the Light Detection and Ranging (LIDAR) instrumentation. Discussions are underway with the French regarding the possibility of this becoming a cooperative project.

*Operational statellite improvement program (OSIP)*

The objective of operational satellite improvement program is to perform research and development activities leading to the definition of advance sensors, spacecraft subsystems, and ground equipment for the meteorological satellites operated by NOAA. Current activities include the development of the solar backscatter ultraviolet (SBUV) instrument for monitoring of ozone fluctuations in the upper atmosphere; assessment of temperature and moisture profiles acquired by the visible/infrared spin scan radiometer/atmospheric sounder (VAS) aboard GOES–4 and GOES–5; and implementation of improvements to the high resolution infrared sounder (HIRS).

Delivery of the first unit of the solar backscatter ultraviolet instrument for integration and launch on NOAA–F occurred in 1983. The design of the high resolution infrared sounder instrument improvements in in process and will be implemented in the units to be flown on NOAA–H, I and J. The NASA Operational Satellite Improvement program is being phased out in FY 1984.

No FY 1985 funding is required.

*Earth radiation budget experiment*

The objective of the Earth Radiation Budget Experiment (ERBE) is to measure the temporal and spatial variations in the Earth's radiation budget to gain basic insight into the causes for climatic fluctuations.

Experimental Earth radiation budget instruments have been flow on the Nimbus satellites. Sampling studies based on those experiments have shown that adequate global coverage requires a multiple satellite system. These studies also indicate the need for improved calibration of the sensors and measurements covering at least one full cycle of seasons. In order to provide adequate and meaningful coverage, indentical Earth radiation budget instruments will be installed on the NOAA–F and G satellites and on one dedicated NASA observatory. The scientific objectives and measurement requirements were developed by a combined NOAA/NASA/university/industry team of scientists.

Development of the ERBE instruments is complete and sensors have been delivered for NOAA–F and ERBS; delivery for NOAA–G will occur in early 1984.

In addition to the ERBE instruments, the NASA observatory will carry the Stratospheric Aerosol and Gas Experiment (SAGE II). This instrument, which will provide aerosol measurement data, has been delivered and integrated with the observatory.

The Earth Radiation Budget Satellite (ERBS) was completed in 1983, including instrument integration. Environmental testing will be completed in early 1984 with shipment of the observatory to the Kennedy Space Center in mid-1984. The ERBS observatory will be launched by the Shuttle to an altitude of 300 km and will then be propelled to the operational altitude of 600 km by an auxiliary onboard propulsion system. ERBS and NOAA–F are scheduled for launch in 1984 NOAA–G is scheduled for launch in 1986.

The FY 1985 funding is required to support the operation and data acquisition of ERBS and NOAA–F and analysis of the data for updating the climate models.

*Extended mission operations (environmental observations)*

The objectives of the extended mission operations is to provice for the operations, data processing, validation and data analysis of missions which have completed basis operations.

Launched in 1978, the Nimbus-7 spacecraft continues to provide significant quanties of global data on sea ice coverage, atmospheric dynamics and chemistry, the Earth's radiation budget, ocean temperature and ocean color. Preliminary evaluation of data has demonstrated the utility of these measurements, and the instrument techniques are being used on operational satellites. Reduction and validation of this data is continuing, as is the operation of the satellites themselves. There is a strong demand for historical and current data on radiation budget, atmospheric dynamics, and trace constitutent concentrations and distribution; all of this data is used for global weather trend studies, severe storm analysis and prediction, improved numerical forecast models, ozone concentration trend analysis, and Earth climate studies.

Data analysis of measurements provided by the Stratospheric Aerosol and Gas Experiment (SAGE), which was launched in January 1979, will be completed in FY 1984.

The Solar Mesosphere Explorer (SME), launched in October 1981, is providing major imput into our overall atmospheric parameter data base. SME is producing simultaneous measurements needed to understand the complex chemical processes taking place in the mesosphere, including data measurements of ozone, atomic oxygen nitric oxide and temperature. All instruments are functioning well. Early data results indicate greater short-term variations and magnitude than was expected of many of the mesospheric properties. SME also continues to make measurements of the El Chichon volcanic cloud. Not only is this data valuable for understanding the short-term impact of volcanoes on the Earth's atmosphere, but it will provide data for use in the study of El Chichon's long-term effect on the climate. A ground truth program to aid in the validation of the SME data is also being undertaken.

Solar terrestrial research activities rely on data received from the International Sun-Earth Explorers, the Interplanetary Monitoring Platform (IMP), and the Dynamic Explorers which are still operational. The ISEE–3 spacecraft, renamed the International Cometary Explorer (ICE), is presently travelling toward a rendezvous with the Giacobini-Zinner Comet in 1985.

FY 1985 funding is required to support mission operations and data analysis activities on the International Cometary Explorer, the Interplanetary Monitoring Platform and the Dynamic Explorers. Activities will also begin in FY 1985 for possible extended operations support of the Active Magnetospheric Particle Tracer Explorer. Operation, processing, and validation of data from Nimbus and SME satellites will be continued in FY 1985 as will activities to provide ground truth for a NASA-developed ozone instrument to be flown on a NOAA weather satellite. These satellites continue to produce extremely valuable data on ozone concentrations which will be used to estimate the occurrence of natural variations, sea surface temperatures, aerosol measurements, and ocean productivity. In addition, necessary correlative ground truth activities will be continued in FY 1985; these *in situ* observations are needed to verify the quality or remote observations and improve our ability to interpret them.

In FY 1985, extended mission operations and data analysis support will be provided for the Earth Radiation Budget Experiment (ERBE), which is planned for launch in 1984, and the International Cometary Explorer (formerly named ISEE–3) which will rendezvous with the Giacobini-Zinner Comet.

*Upper atmosphere research satellite program*

The Upper Atmosphere Research Satellite (UARS) program is the next logical step in conducting a comprehensive program of research, technology development and monitoring of the upper atmosphere aimed at improving basic scientific understanding. This mission is essential for understanding the key radiative, chemical and dynamical processes which couple together to control the composition and structure of the stratosphere. The UARS mission will provide the first integrated global measurements of: ozone concentration; chemical species that affect ozone; energy inputs; temperature; and winds in the stratosphere and mesosphere. These measurements will complement the measurements of ozone and of atmospheric parameters affecting ozone that were made on Nimbus and SAGE. The UARS program is a critical element in NASA's overall stratospheric research and monitoring efforts; it will provide the first full data set on stratospheric composition and dynamics which will be required when very difficult decisions must be made in the future regarding production of chlorofluorocarbons. The UARS mission will also contribute to the assessment of the impact of stratospheric changes on our climate and will provide the data needed for a full understanding of the stratosphere. These understandings are essential for subsequent design and implementation of a long-term stratospheric monitoring activity.

A final selection of eleven experiments has been made, including infrared and microwave limb sounders requiring advances in cryogenics, solid-state devices and microwave antennas beyond earlier

capabilities. The instrument design and development activities are underway; also the central ground data handling facility, which will permit interactive utilization of data shortly after they are taken by the twenty-one design and theoretical investigator teams, is being defined. Preparations for initiation of procurement activities for the UARS mission are also underway.

The planning estimate of the UARS mission is in the $630–700 million range. A total of 90–100 direct civil service manyears is required in FY 1985 to support the UARS design and development activities, and a total of 560–570 direct manyears is required to support the UARS mission through launch in late 1989.

The FY 1985 funds are required for continuation of the design and development of the UARS instruments, for continuation of science team research and algorithm development, for continued definition of design requirements for the ground data handling facility, and for initiation of the spacecraft design and development activities.

The instruments continue to be the long-lead time elements of the UARS program. Although there is considerable technological heritage for these instruments, timely development and testing requires that substantial instrument design and interface definition effort be accomplished in FY 1985. In addition, procurement of long-lead spacecraft elements must be initiated in FY 1985.

The ground data handling facility will enable a higher level of interaction among experimenters and theoreticians than has existed with past programs. Implementaiton of this concept requires that it be designed early in the UARS design and development activities so that individual experiment data processing subsystems, including algorithms, and the interactive data base can be designed for maximum interaction and effectiveness.

*Interdisciplinary research*

Interdisciplinary research activities need to be conducted to quantitatively characterize chemical, physical, and biological porcesses on the land, along with the interactions between the land, the Earth's oceans, and atmosphere, which are of particular importance in assessing the impact of these phenomena on global, physical, and biogeochemical processes. Such research is essential to investigating and assessing long-term physical, chemical, and biological trends and changes in the Earth's environment.

In FY 1985, initiation of interdisciplinary studies is required to integrate the discipline-specific research activities of Oceanic Processes, Atmospheric Dynamics and Radition, Upper Atmosphere/ Tropospheric Chemistry, and Land Processes into a unified program which will help increase our understanding of critical global processes. Emphasis will be placed on initiating specific pilot studies in land-atmosphere and ocean-atmosphere interactions in energy, water, and key nutrient cycles.

*Tethered satellite payloads*

The Tethered Satellite System (TSS) will provide a new facility for conducting experiments weighing 500 kg or less from distances of 100 km above or below the Space Shuttle. The TSS will allow unique science to be undertaken such as observations of atmospher-

ic processes occurring within the lower thermosphere (below 180 km altitude), new observations of crustal geomagnetic phenomena, and direct observation of magnetospheric-ionospheric-atmospheric coupling processes in the 125–180 kilometer region. In addition, the satellite, coupled to the conducting tether, can generate large amplitude hydromagnetic waves and electrodynamic waves in the local space plasma; thus enabling active space plasma and magnetospheric physics experiments to be performed. The objective of the initial TSS mission is to verify the controlled deployment, retrival and on-station stabilization of the satellite tethered from the orbiter, and to carry out scientific research using a conducting tether extended 20 km above the orbiter. NASA is providing the scientific payloads for the initial flight of the TSS which is scheduled for launch in 1987.

The TSS is an international cooperative project with the Italian government, wherein the United States is developing the tether deployment system, is responsible for overall project management, system integration, and flight on the Shuttle, and for development of the instruments to be flown on the first mission. Italy is developing the satellite and is responsible for instrument and experiment integration into the Tethered Satellite.

The FY 1985 funding is required to initiate the design and development of the scientific instruments for the first test flight of the Tethered Satellite System which is scheduled for launch in 1987.

*Scatterometer*

The purpose of the Navy Remote Ocean Sensing System (N-ROSS) is to acquire global ocean data for operational and research usage by both the military and civil sectors; and a Scatterometer sensor is required to meet the objectives of this mission. NASA will provide the Scatterometer sensor and the Department of Defense will provide the N-ROSS spacecraft and launch services for a launch in late 1988.

The Scatterometer will provide accurate, global measurements of ocean surface winds which will be useful for both oceanography and meterorology. In addition to satisfying Navy operational requirements for providing wind field data, Scatterometer data will permit the first global study of the influence of winds on ocean circulation, provide data on feedback effects of the oceans on the atmosphere, and provide improved marine forecasting (winds and waves). Flight of the N-ROSS in late 1988 will provide an overlap of data gathering with the World Ocean Circulation Experiment planned by the international oceanographic community. The feasibility of using the Scatterometer technique from space to accurately measure wind was demonstrated by Seasat in 1978.

Definition studies conducted by NASA during FY 1983 and early FY 1984 have resulted in a determination that the performance requirements as stated jointly by the research community and the Navy can be satisfied by utilizing system design concepts similar to those used on the Seasat Scatterometer. The major improvements include the addition of two antennas for improved wind direction determination and the addition of digital filtering to compensate for earth rotational effects. Additionally, preliminary definition of a ground data processor, which will utilize research quality algo-

rithms to process the Scatterometer raw data into geophysical product for utilization by the oceanographic and meteorological research communities, has been completed.

In FY 1985, design and development of the N-ROSS Scatterometer will be initiated leading to the scheduled launch in late 1988. In particular, long-lead time contracts must be initiated in FY 1985.

## Materials Processing in Space Program

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Research and analysis | $11,700,000 |
| Materials experiment operations | 11,300,000 |
| Total | 23,000,000 |

The Materials Processing in Space program emphasizes the science and technology of processing materials to understand constraints imposed by gravitational forces and the unique capabilities made possible by controlling these processes in the space environment. Ground-based research, technology development, and payload definition activities in FY 1984 are being concentrated on six major processing areas: metals and alloys, electronic material, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena. These activities will provide the scientific basis for future space applications of materials processing technology as well as providing a better understanding of how these processes occur on the ground. Definition studies will be performed for Shuttle experiment candidates in areas such as containerless experiments, combustion science, solidification and crystal growth, and blood storage. Also included are maintenance of capabilities for experimentation in drop tubes and towers, and aircraft. An outreach program, consisting of technical publications, workshops, experiment accommodation studies and support for Joint Endeavor and Technical Exchange Agreements, are included in this program.

Materials Experiment Operations is a consolidation of ongoing activities which provide a range of experimental capabilities for all scientific and commercial participants in the materials processing program. These include Shuttle mid-deck experiments, the Materials Experiment Assembly and the Materials Science Laboratory, which is carried in the orbiter bay. These capabilities will enable users to develop different experiments in a cost-effective manner and allow a better understanding of the technical risks associated with experiment concepts before attempting to develop more complex hardware. In addition, reflight of investigations on Shuttle/Spacelab missions and the mid-deck is provided for in Materials Experiment Operations.

*Research and analysis*

The research and analysis activity provides the scientific foundation for all current and future projects in the microgravity science and applications program. Emphasis is placed on ground-based research which is expected to evolve into space investigations with potential for future applications. This activity also supports technology development for future ground and space capabilities, and

commercialization activities leading toward privately funded space enterprises. Most research projects are initiated as a result of proposals from the scientific community which are extensively peer reviewed prior to selection. The FY 1984 funding is being used to support ongoing research in infrared detector materials, spherical shell technology, floating zone crystal growth, separation and synthesis of biological materials, fluid flow effects in materials processing, combustion science, and containerless processing techniques. Commercialization activities will continue with studies of institutional arrangements associated with joint NASA/industry ventures, information activities directed toward industry involvement in microgravity science and applications projects, and early negotiations and continuing technical support with companies interested in undertaking joint space endeavors wtih NASA.

Ground-based research and analysis will be continued in FY 1985 in the areas of metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, fluid dynamics and transport phenomena. Research will be conducted to define the role of gravity-driven influences in generic processing methods. Effort will also be continued on establishment of university centers for bioprocessing research and a microgravity research lab at the Lewis Research Center. In addition, FY 1985 funding is required to support the physics and chemistry experiments in space (PACE) activities which were previously funded by the Office of Aeronautics and Space Technology (OAST). These activities are being transferred from OAST as the technology has been developed to the point where it is now ready for potential application in space.

*Materials experiment operations*

The materials experiment operations program provides a wide range of opportunities for scientific and commercial experiment in microgravity science and applications. Development of Shuttle middeck experiments are supported under this activity. The first materials experiment assembly hardware was launched in 1983, and early data analysis has shown promising results.

FY 1985 funding is required to continue basic and applied research activities using mid-deck and cargo bay experiments leading to several flights over the next few years which will include investigations using the first version of the acoustic containerless processing equipment and the first low gravity test of a method (isoelectric focused electrophoresis) for the separation of biological materials.

## Communications Program

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Research and analysis | $9,100,000 |
| Search and rescue | 2,400,000 |
| Technical consultation and support studies | 2,900,000 |
| Experiment coordination and operations support | 1,200,000 |
| Advanced communications technology satellite flight program | 45,000,000 |
| Total | 60,600,000 |

In FY 1984, the research and analysis program continues to support the development of component and device technology required

by NASA, other government agencies, and U.S. industry for advanced communications satellite systems. This technology development will address requirements identified in recent tests of proof-of-concept hardware associated with the Advanced Communications Technology Satellite (ACTS) program and Department of Defense programs.

The Search and Rescue program is an international cooperative program that demonstrates the use of satellite technology to detect and locate aircraft or vessels in distress. The United States, Canada, France, and the Soviet Union developed the system, in which Norway, the United Kingdom, and Sweden also participated. Two COSPAS satellites and one Search and Rescue-equipped satellite (NOAA-E) are currently in operation. Over 120 lives have been saved in numerous incidents in Canada, the U.S., and Western Europe, and the list continues to grow on a weekly basis.

The technical consultation and support program will continue to provide for studies of radio interference, propagation, and special systems required for the growth of existing satellite services and the extension of new satellite applications. Support to the Department of State, the Federal Communications Commission, the National Telecommunications and Information Administration, and the Federal Emergency Management Agency in the development of frequency and orbit sharing techniques and strategies for upcoming World Administrative Radio Conferences (WARC's) will continue.

The experiment coordination and operations support program assists other federal agencies and public sector organizations in the development of experimental satellite communications for emergency, disaster and public service applications. The Applications Technology Satellities (ATS) 1, 3 and 5 will continue operating until FY 1985, at which time operations will be transferred to universities.

For the Advanced Communications Technology Satellite (ACTS) flight program, technology development and testing will be continued in FY 1984 on components for future communication satellites.

*Research and analysis*

The Communications Research and Analysis program provides the high-risk technology required to ensure continued U.S. preeminence in the field of satellite communications. In FY 1983, the preliminary phase of the proof-of-concept program was successfully completed. This program demonstrated the laboratory feasibility of technology needed to alleviate orbit and radio frequency spectrum congestion and enable cost-effective growth in the capacity of communication satellite systems.

FY 1984 efforts will concentrate on the continuing development of large-scale integrated circuit functions needed to reduce power and weight of a flight baseband processor for future communication satellites. The implementation of various approaches to a more practical and efficient hardware design for modulator/demodulators for the baseband processor will begin, and the development of high efficiency and low cost traveling wave tube transmitters for space and ground terminal applications will be initiated. The development of proof-of-concept 30 GHz solid state ground terminal transmitters and antennas will be completed and preparation for

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the development of transmitter applications of 20 GHz devices will get underway. In-house evaluation of proof-of-concept hardware, integrated into an ACTS/type transponder, is being initiated in FY 1984. Intersatellite link technology, which emphasizes the development of devices and components, will be continued with the focus on preliminary proof-of-concept hardware design.

Research and analysis efforts are also directed toward defining the ground segment (i.e., mobile and base station equipment) and networking technology for a first generation mobile communications satellite service. This is a joint study with industry and Canada to define a two-way radio, radio telephone and low-speed message and data service to mobile terminals operating in rural and non-metropolitan areas. In November 1983, NASA signed an agreement with the Canadian Department of Communications to cooperate in the definition phase of the program. In FY 1984, a Notice of Opportunity will be released to solicit U.S. industry participation.

During FY 1985, the Communications and research and analysis program will continue to address unresolved technology issues and risk-reducing tasks related to the proof-of-concept program in support of future communication satellites. In addition, definition of 20 GHz solid state transmitters utilizing improved devices will be initiated. In-house evaluation of the proof-of-concept transponders will continue in FY 1985 under simulated space flight conditions in support of the ACTS flight program. Radiation hardening of baseband processor memory circuits will also be undertaken in FY 1985. The development of traveling wave tube transmitters (space and ground) and intersatellite link transmitters (space) will be continued. Ground terminal technology efforts will include proof-of-concept modems, codecs and field effect transistor, low noise receivers. Monolithic technology for large matrix switch arrays and antenna beam forming networks will also be pursued. All appropriate research and analysis efforts will continue to be coordinated with the Department of Defense. In FY 1985, mobile terminal breadboard development will be completed.

In addition to broadband spectrum and orbit conserving technologies, very high data rate technologies associated with future Shuttle payloads, low-earth orbital platforms and geosynchronous platforms will be continued in FY 1985. Low data rate technologies for public service, disaster/emergency and law enforcement applications will also be pursued, and studies to define advanced communications system concepts and requirements will be initiated.

*Search and rescue*

The Search and Rescue program is demonstrating the feasibility of using satellites to significantly improve the capability of search and rescue forces to detect and locate general aviation aircraft and marine vessels during emergencies. This satellite system provides comprehensive coverage which enables rescue forces to arrive at accident scenes quickly.

The first satellite within the framework of the joint COSPAS/SARSAT project was launched by the Soviet Union on June 30, 1982. In March 1983, the second COSPAS satellite and the first SARSAT-equipped satellite, NOAA–E, was successfully launched.

All three of the satellites are operating quite well. Ground stations and control centers are in regular operation in the United States, Canada, France, the USSR, Norway, and the United Kingdom. The performance of the combined satellite/ground system has equaled or exceeded expectations in terms of sensitivity, accuracy, and ground coverage.

Although the demonstration and evaluation phase of the program has just begun, the results achieved to date indicate that the demonstration will be a success and that an operational system can be implemented. The next five NOAA satellites will be equipped with SARSAT instruments providing two-satellite coverage for the balance of the 1980's.

During FY 1985, work on the NOAA-H, -I, and -J spacecraft, and improvements to the ground stations, will be completed. Beginning in 1985, the major emphasis of the search and rescue program will shift from providing basic spacecraft and ground system coverage at 121.5 MHz, which has been the central focus of the program since 1978, to research and development activities required to permit the most effective possible operational system for the 1990's, based on a 406 MHz system.

The development of distress transmitters will be continued in FY 1985 and experiments using geosynchronous spacecraft to relay 406 MHz signals to complement the polar satellites will be conducted. In addition, a special purpose ground station compatible only with the 406 MHz system will be developed as a prototype for the potential international system of the 1990's.

*Technical consultation and support studies*

The technical consultation and support program provides the technical basis for regulatory and policy development needed to assure the orderly growth of existing and new satellite services. Unique analytical tools are developed and used to solve problems of inter- and intra-satellite/terrestrial system interference. Emphasis is placed on on-orbit and spectrum utilization studies, which include the development of frequency and orbit sharing techniques and strategies, design standards, and the determination of the effect of propagation phenomena and man-made noise on performance, design, and efficient use of the geostationary orbit and radio spectrum.

Program personnel recently completed three years of preparation for, and participated in, the 1983 Region 2 Administrative Radio Conference on planning for the Broadcast Satellite Service in the Western Hemisphere. Numerous technical and policy papers were prepared to provide the foundation for U.S. positions, many of which were ultimately adopted. A special spectrum and orbit utilization computer program was developed and chosen as an international standard for analyzing intersystem interference. Other accomplishments include the anticipated initiation of a Public Rulemaking Proceeding in the early spring of 1984 to establish a commercial Land Mobile Satellite Service. This Proceeding is the culmination of almost ten years of technology development, economic analyses, user experiments, propagation studies, and regulatory proceedings. The end product is expected to be a commercial service owned and operated by the private sector by 1988.

Major emphasis during FY 1985 will continue on studies, experiments, spectrum and orbit utilization computer program updating, and regulatory processes, to assure the growth of space communications and bring into being new capabilities in data collection, multifunctional/multifrequency satellites, and thin-route communications. U.S. strategies, positions, and technologies will be developed and propagation experiments conducted to support U.S. positions at three International Telecommunications Union World Administrative Radio Conferences to be held in Geneva during the 1985–1988 time frame. Decisions reached at these conferences will directly affect our country's access to the geostationary orbit and radio spectrum.

*Experiment coordination and operations support*

The objective of this program is to appropriately document and archive a wide range of user experiments and demonstrations in the application of satellite communications. Past experiments on experimental satellites such as the Applications Technology Satellite (ATS) series and the Communications Technology Satellite (CTS), have generated great interest nationally and internationally in satellite telecommunications. Nearly 400 communications experiments using the ATS series and CTS have been successfully conducted during the extended lifetime of these satellites, thus providing users with the experience necessary for making informed decisions regarding their communications functions. NASA's stimulus in encouraging use of these unique facilities has led to wider application of commercial satellites, which can better meet the need for flexibility and continuity of services.

More than twenty organizations are currently using the ATS–1 and ATS–3 satellites for communication experiments. ATS–3 is supporting emergency medical experiments conducted in conjunction with the Southern Regional Medical Consortium (SRMC). The SRMC experiments determine the value and cost effectiveness of mobile communications via satellite for emergency notification, vehicle dispatch, and two-way voice and biomedical telemetry between paramedics and hospital physicians. Efforts toward rural, wilderness, and offshore oil rig applications are emphasized. Similarly, in the Pacific basin, ATS–1 connects 22 islands and provides disaster relief, medical, educational, and emergency service. ATS–1 has recently been repositioned from 149°W to 198°W longitude in an effort to extend its useful life to the Pacific users. This satellite service has been a valuable asset to Pacific users who, prior to ATS–1, received their news 24 hours after the fact.

Operational support for ATS–1 will be assumed by the University of Hawaii and for ATS–3 by the University of Miami in FY 1985, when the NASA Satellite Tracking and Data Network (STDN) facilities are dismantled. NASA will continue to maintain approval and policy control of the ATS program. Other FY 1985 activities will include continued planning for educational and public service communications; the development of low-cost Intelsat compatible ground terminals and alpha-numeric portable ground terminals; and the continuing support for the management and operation of the Denver Satellite Access Facility. The definition of experiments for a Advanced Communications Technology Satellite (ACTS) test

program, and the Mobile Satellite will be also continued in FY 1985.

*Advanced communications technology satellite*

The objective of the Advanced Communications Technology Satellite (ACTS) program is to prove the feasibility of certain advanced communications satellite technologies through a flight test program. The specific technologies to be validated include; (a) the use of multiple fixed and scanning spot antenna beams; (b) frequency reuse; (c) beam interconnectivity at both intermediate frequencies and at baseband; (d) advanced system network concepts; and (3) dynamic rain-compensation techniques. These technologies will be applicable to a wide range of communications systems in the 1990's.

The ACTS program is the fruition of several years of technology development supported by NASA in the field of advanced communications satellite systems. It is an extension of the same principles which were previously applied to the development of the Advanced Technology Satellite (ATS–6) which was launched in 1974. ATS provided the basis for the current generation of geosynchronous communications satellites and the technology which has allowed American industry to dominate this field since its inception. Similarly, an ACTS flight program is critical to demonstrating that the complex architecture and critical timing associated with today's advanced-state-of-the-art space communications system is operationally practical.

Based on ATS–6, industry has provided many technological advances and breakthroughs in this area of space technology through private investment and R&D. However, it has been shown that a background NASA program which supports work in system design and architecture through periodic flight programs is necessary to maintain the vitality and technological viability of the American satellite industry. (Like ATS–6 and ACTS, these programs are too costly and high risk to be privately funded.) This is especially true in the current environment of heavily subsidized foreign challenges from several countries. Similar to the inputs to industry R&D, military developments have provided important core technology to the industry, some of which applies to commercial communications satellites. However, in this case, the basic requirements of military systems (e.g., low data rates with complex extraction of weak signals and survivability) result in overall designs not applicable to the needs of commercial users which are characterized by high data rate and low cost).

The ACTS system itself is predicated on the last few years of research and development sponsored by NASA in key areas of component and device technology oriented toward "spectrum conservative techniques" and applicable to all types of commercial communications satellites (C, Ku and Ka band). In essence, this term implies improving the useful information through put, and therefore the efficiency and cost effectiveness, of these satellites. The ACTS system contains many technological innovations, each of which contribute to this goal. This system can only be proven and developed for commercial use through experimentation with a flight system and its interaction with a wide variety of user ground sta-

tions. Over thirty-five potential experimenters have committed to NASA to experiment with the ACTS system at their own expense.

FY 1985 funding is required to continue ACTS technology development and activities leading to the flight program.

INFORMATION SYSTEMS PROGRAM

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Data systems | $8,400,000 |
| Information systems | 7,800,000 |
| Total | 16,200,000 |

The objectives of the Information Systems program are to: develop and demonstrate advanced capabilities of managing, distributing, and processing data and information; implement information systems standards and provide common software in order to lower data systems costs; and develop the basis for data services to provide improved access to, and rapid delivery of, space data and advanced data systems in support of the Nation's satellite programs and the space science and applications projects.

This program provides for timely development of data system capabilities to meet the needs of flight missions and major space science an applications programs. The early demonstration of capabilities has a high potential for reducing ground data systems development risks and the chance of late data delivery.

The FY 1985 Information Systems funding is required to provide support for space science and applications programs. Specifically, funds are required to continue development of the oceans, climate, planetary, and land pilot projects, which are system engineered to support those disciplines at the Jet Propulsion Laboratory, Goddard Space Flight Center, and universities; to complete implementation of on-line catalogs and common software for climate, oceans, and land data which support ongoing research; and to continue development of data management and data archiving with flight projects, discipline program offices, and other NASA program offices. In addition, the FY 1985 funding is required to support operation of the Science and Applications Computer Center, the National Space Science Data Center, and the Hi-Speed Vector Computing Facility at the Goddard Space Flight Center. Operation of these facilities was previously funded within Physis and Astronomy Mission Operations and Data Analysis and the Environmental Observations Program.

7. TECHNOLOGY UTILIZATION, $9,500,000

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Technology dissemination | $5,800,000 |
| Technology applications | 3,700,000 |
| Total | 9,500,000 |

The NASA Technology Utilization Program enhances the national economy and industrial productivity through a series of interactive processes designed to transfer aerospace technology evolving from NASA's R&D base to nonaerospace sections of the U.S. economy. Almost every part of the U.S. industry is touched by the transfer process, especially such areas as automation, electronics, and

materials. In the public sector, medicine, rehabilitation, and safety are but a few of the areas receiving benefit. The specific objectives of the program are:

Acceleration and facilitation of the application and use of new technology, thus shortening the time between generations of advanced aeronautics and space technologies and their infusion into the economy;

Encouragement of multiple secondary uses of NASA technology in industry, education, and Government, where a wide spectrum of technological problems and needs exist;

Understanding more fully the technology transfer process and its impact on the economy; and

Development of applications of NASA's aerospace expertise, with its technology, technologists and unique facilities, to priority nonareospace needs of the Nation.

Since the Program's inception in FY 1962, many transfer mechanisms have been developed to facilitate the use of aerospace technology in the public and private sectors of the economy. These mechanisms include publications and announcements, industrial conferences, and seminars. Through such efforts, NASA has developed a viable working relationship with U.S. industry across a broad front of commercial enterprises. In FY 1985, NASA proposes to build on its technology transfer activities to stengthen expanded Government-industry cooperation.

Conversion of *NASA Tech Briefs,* one of the NASA's principal new technology transfer and announcement mechanisms, to commercially viable, private sector publication, is scheduled for implementation in FY 1985. Pending this conversion, NASA has continued the free distribution of *NASA Tech Briefs* to 75,000 industrial scientists, engineers and businessmen on a quarterly basis to stimulate and promote secondary application and use of NASA-developed technologies for commercial purposes. It is anticipated that subscriber circulation will grow beyond the current level as a private sector periodical.

During the past year, thousands of U.S. industrial firms have been provided computerized access to NASA information through the NASA-sponsored dissemination center network. Technology transfer services growing out of this information, have focused on a wide array of problems specified by network industrial clients. These firms, especially those in the industrial manufacturing and research sectors, have found network information and technology transfer services to be beneficial in the development of new or improved products or processes. The NASA-supported center for computer software dissemination realized the highest level of activity yet in the sale/lease of NASA-developed computer programs for industrial use. Overall, the entire university-based dissemination network received nearly $4.5 million from industry last year for information products and technology transfer services, underscoring the continued interest and importance which these programs have in industry.

Emphasis during FY 1983 placed on bioengineering, rehabilitation, manufacturing, and automation applications. Most of the projects funded during FY 1983 had joint participation from user agencies or industry. A major milestone was reached in bioengineering,

when industry received the Food and Drug Administration's approval to implant numerous automatic defibrillators in human subjects. In addition, the Federal Emergency Management Agency and industry adopted a NASA simulation concept to train firefighters; and industry has committed to apply NASA composite technology to several new industrial concepts. Two other highlights during FY 1983 were the commitment of industry to develop the percutaneous shunt, which is an ion beam textured pyrolytic carbon device that allows quicker and less painful access to the bloodstream for hemodyalysis, chemotherapy, etc.; and Klystron, power-efficient microwave tubes for communication, such as TV broadcasting.

### Technology Dissemination

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Technology dissemination | $5,800,000 |

In FY 1985, NASA will continue to realign and improve its technology dissemination system, with particular emphasis on system efficiencies, centralization of information search capabilities, and modernization of the communications media. Such efforts will reduce technology transfer unit cost, improve capabilities to serve broader industrial user markets nationwide, and increase information product systems to match critical technological needs in industry. Realignment and restructuring of NASA dissemination programs will also be acomplished to promote greater awareness and involvement of State governments in relation to their initiatives to enhance the technological and economic growth of their respective industries. Particular effort will be made to serve high technology firms and high growth areas in U.S. industry through closer interactive processes between industrial users and NASA scientific and engineering capabilities.

In addition, NASA will encourage private sector involvement in commercialization of space and use of space-related technologies for industrial research and development purposes. Such efforts will include the conduct of NASA executive management symposia for major U.S. nonaerospace firms, analyses of extended commercial markets dependent upon NASA-developed technology, etc.

### Technology Applications

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Technology applications | $3,700,000 |

In FY 1985, NASA will consolidate the transfer of NASA-developed technologies into three main thrusts: automation and electronics; materials; and bioengineering and rehabilitation.

The overall objective of each of these thrusts will be to transfer aerospace technology through adaptive or applications engineering projects supported by industry or interagency cost-sharing. NASA will participate with industry, other federal agencies and universities to support several high priority engineering projects. Applications team activities will be maintained in support of selected feasibility studies designed to apply existing aerospace technology to electronics, materials and industrial automation problems identified in cooperation with other government agencies, public sector

medical organizations, universities and industry. Rural applications team activities will be continued.

### 8. AERONAUTICAL RESEARCH AND TECHNOLOGY, $347,400,000

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Research and technology base | $228,300,000 |
| Systems technology programs | 119,100,000 |
| Total | 347,400,000 |

The objective of the aeronautical research and technology program is to conduct an effective and productive program that contributes materially to the enduring preeminence of U.S. civil and military aviation by conducting appropriate disciplinary and systems research at the leading edge of technology in those areas critical to the continued superiority of U.S. aircraft; maintaining the research centers in positions of excellence in facilities and technical staff; assuring timely transfer of research results to the U.S. aeronautical industry; assuring appropriate involvement of universities and industry; and providing aeronautical development support to other government agencies and U.S. industry. Conducted well in advance of and independent of specific applications, the aeronautical research and technology program includes both fundamental research in the aeronautical disciplines and systems research directed at interaction among disciplines, components, and subsystems applicable to general classes of advanced military and civil aircraft. The program involves participation by aeronautical manufacturers to ensure that the technology is compatible with practical design considerations and can be successfully transferred into use.

The FY 1985 estimates reflect the need to continue efforts both in the basic aeronautical disciplines and in areas of systems research and to maintain specialized facilities essential to aeronautical research.

Continuing emphisis in fluid and thermal physics will center on high Reynolds number cryogenic testing and turbulent drag reduction, while new emphasis will be applied to vortex flows and geometric modeling of, and grid generation for, complex aircraft configurations for advance applications of computational aerodynamics. Areas of emphasis in materials and structures will include light alloy metals, new composite materials, high-temperature ceramics for heat engines, and the crash dynamics of composite structures. In the controls and guidance and human factors areas, research emphasis will be on flying qualities for highly augmented-controls aircraft, validation methodology for fault-tolerant systems, the human factors of advanced crew station automation, and the development of technology for improved simulation fidelity. In computer science, the major emphasis will be in concurrent processing architectures, algorithms, and techniques to support the agency's computational fluid physics research. Continued support of the two computer science research institutes and the university program will provide a strong research base in this critical area. In the numerical aerodynamic simulation program, the processing system development will continue with emphasis on bringing the first high-speed procesor to full operational status by 1986.

In propulsion, emphasis will be placed on a broad spectrum of technologies offering the opportunity for potential advances. These include intermittent combustion engines for small aircraft; turbine engine components including inlets, nozzles, compressors, turbines, and combustors; and turbine engine systems technologies encompassing controls, gears, bearings, engine dynamics and stall recovery. Rotorcraft research will stress noise and vibration reduction and the unsteady aerodynamics of rotors. Areas of emphasis in high-performance aircraft research will include high angle-of-attack flight, vectored thrust and short takeoff/vertical landing, supersonic cruise/maneuverable aircraft, hypersonic propulsion, structures and configuration aerodynamics, and propulsion/airframe controls integration. Also included are efforts in the turbine engine hot section technology program to increase engine performance and durability. In subsonic aircraft research, emphasis will be placed on advance composite structures technology, icing and lightning research, natural and controlled laminar flow, and technology problem areas identified in coordination with the Federal Aviation Administration (FAA) as critical to improved air safety and operations.

RESEARCH AND TECHNOLOGY BASE

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Fluid and thermal physics research and technology | $49,000,000 |
| Materials and structures research and technology | 25,000,000 |
| Controls and guidance research and technology | 12,800,000 |
| Human factors research and technology | 10,900,000 |
| Multidisciplinary research | 6,100,000 |
| Computer science and applications research and technology | 23,800,000 |
| Propulsion systems research and technology | 23,000,000 |
| Rotorcraft research and technology | 27,000,000 |
| High-performance aircraft research and technology | 41,500,000 |
| Subsonic aircraft research and technology | 20,200,000 |
| *General reduction* | *−11,000,000* |
| Total | 228,300,000 |

*Fluid and thermal physics research and technology*

The fluid and thermal physics research and technology program is a combined analytical and experimental research effort directed at external and internal aerodynamics. One of its principal objectives is the development of computational methods for the prediction and/or simulation of complex fluid flows over aircraft and within inlets, flow passages, and exhaust ducts of turbomachinery. A second objective is the maintenance of a coordinated experimental test program to provide insight into the fundamentals of flow physics, and to provide required detailed flow measurements for verification and validation of prediction and simulation methods. The experimental program also includes the development of advanced test methods and instrumentation to provide for increased accuracy and productivity of NASA wind tunnels and developmental facilities. Rapid progress is being made in the development of computational techniques for complex flow configurations that will lead to reduced development time and costs for future aircraft and

will provide the basis for achieving new and higher levels of aircraft and missile performance.

A key goal of the computational fluid dynamics research is to provide a means for calculation of aerodynamic forces and moments acting on a complete aircraft under all conditions of attitude, speed, and altitude. The second part of this goal is the development of algorithms and predictive codes for gas glows over compressor and turbine blades and within the duct passages of gas turbine engines. During the past year, several schemes have been developed, yielding improved speed and accuracy but utilizing existing mathematical formulations. Of these, an outstanding example is a method in which simple rectangualr grids form the network on which finite volume calculations are carried out. The simplicity of the method provides surprising accuracy when handling very complex three dimensional aerodynamic shapes. In other studies of flow over wings and bodies at transonic speeds, calculation times have been reduced by factors of three to ten for the difficult but precise Euler equations of fluid motion; this mathematical advance being equivalent to the development of a computer with three to ten times the speed of current machines. In parallel with the work on external flows, substantial progress has been made in the more difficult prediction of transonic flows in compressor and turbine stages of turbomachinery. Recent advances on "schock-free" airfoils for external flows have been adopted for compressor and stator blading resulting in the development of a new computational technique that can now determine geometrical shapes yielding higher efficiency and increased pressure rise per stage.

Turbulent fluid motion continues to be the most difficult flow prediction problem and, while new methods for turbulence modeling have not yet achieved desired increases in accuracy, recent experiments associated with friction drag reduction methods have provided new insight into the structure of turbulent boundary layers on flat and curved surfaces. Studies have demonstrated for the first time the possibility of reducing turbulent friction on aircraft by seven to ten percent, a very significant and economically important reduction. The tests have verified that ruled vee grooves parallel to the flow can achieve the drag reductions even for flow inclinations as great as 15 degrees.

Experimental programs measuring the pressure rise and efficiency of compressor and turbine blade designs have shown detrimental effects of the engine's noise environment on blade performance. The noise and turbulence produced within the engine promotes flow streamline separation on the blade surfaces and limits the pressure rise per stage. As a result of these new findings, design codes are being modified to include and compensate for these effects.

Heat transfer to turbine blades continues to be an important area of research in improving the efficiency and life of gas turbine engines. During the past year, studies of cooling air ports in turbine blades have resulted in the invention of new port configurations which substantially improve the uniformity of cooling with the consequent reduction in cooling air requirements by thirty to forty percent. This reduction of cooling air bleed requirements leads in turn to specific fuel consumption savings of three to five

percent or the enhanced cooling can be traded for increased turbine/blade life and safety.

The National Transonic Facility (NTF) at the NASA Langley Research Center in Hampton, Virginia, completed its final checkouts during 1983 and started its first year of operation in December or 1983. All design goals have been met, and the wind tunnel has been operated over its entire range of temperatures and pressures. This premier facility provides a unique national capability to maintain U.S. preeminence in aeronautical research and development. A wide range of aircraft models has been prepared for testing during FY 1985 by NASA and the aerospace industry. These models include pathfinder military and commercial configurations, aeroelastic models, missile configurations and advanced wing designs.

Studies of test techniques to provide improved wind tunnel test accuracy will be emphasized in fiscal year 1985. These will include magnetic suspension systems for support-free testing in wind tunnels; new concepts for wall corrections in transonic and low-speed high-lift test conditions; nonintrusive laser instruments for direct measurement of velocity, density, and temperature in wind tunnels; and holographic flow visualization techniques.

Computational research will work to achieve solutions of greater geometric complexity and will utilize the more exact Euler and Navier-Stokes equations of motion that are now solvable with the help of the more powerful computer systems available at the NASA research centers. Increased emphasis will be placed on the development of advanced simulation techniques for turbulence and turbulent flows to provide new insight into the coherent structures prevalent in turbulent flows. Recent advances in the understanding of the interaction of viscous boundary layers and external flows will be applied to the problems of streamline separation that occur across the operating ranges of aircraft wings, was well as compressor blades in turbomachinery. A continuing effort will be supported to provide detailed experimental verification of the computational prediction methods.

Research in viscous flow control will explore both the maintenance of laminar boundary layer flow and the reduction of surface friction drag once turbulent conditions have been established. Experiments on transonic laminar flow will continue, utilizing new suction surface materials that are inherently smoother and approach the ideal of uniform suction over a large portion of a wing. Additional study will be made of hybrid systems which suction is applied only over leading portions of the wing surface. Turbulent drag reduction experiments using recently developed turbulent drag reduction devices will be extended to realistic flight conditions, and new and innovative techniques to control the turbulent surface layers will be explored. These research areas offer great promise for reduction of aircraft drag leading, in turn, to increased range and fuel economy.

Combustion studies in the coming year will focus on new problems anticipated for the next generation of high-performance fan or turboprop engines. With the required higher temperatures and pressures following the compression phase of the cycle, new combustor designs may take advantage of higher flame speeds and im-

proved mixing to reduce size and length, and to produce the heat addition in a smoother and more evenly distributed manner. The combustor and the following turbine stages should thereby achieve increased performance and time before failure.

The National Transonic Facility will become fully operational in 1985 and will be heavily utilized by the DOD and industry to finalize new designs and to calibrate existing lower Reynolds number test facilities. This latter function will increase the utility of existing wind tunnels and define those test parameters that are insensitive to Reynolds number variations.

*Materials and structures research and technology*

The objectives of the materials and structures research and technology program are to: (1) investigate and characterize advanced metallic, ceramic, polymer, and composite materials; (2) develop structural concepts and design methods to exploit the use of advanced materials in aircraft; (3) advance analytical and experimental methods for determining the behavior of aircraft structures in flight environments; and (4) generate research data to promote improvements in performance, safety, durability, and economy in civil and military aircraft. Areas of emphasis include high-temperature engine and airframe materials and structural concepts; composite materials application, life prediction, and thermal and dynamic response, including aeroelasticity; and more accurate and efficient integrated design methods for airframes and engines.

Significant improvements in the performance of turbine engines can be realized by increasing engine operating temperature. Ceramic materials offer the best potential for achieving increased operating temperature together with long life. During the past year, new processing methods for ceramics have led to substantial improvements in strength and reliability. A major step in the prediction of coating life for engine turbine blades has been achieved. Combining an analysis for superalloy coating spallation with an analysis of chemical interdiffusion has produced a highly accurate prediction of coating degradation.

Research on airframe materials concentrates on both metals and polymer-matrix composites. Through the use of a powder metallurgy process, small amounts of zirconium added to a common aluminum alloy resulted in nearly doubling the fracture toughness while slightly increasing the yield strength. Such improvements, if realized in commercial production, would save weight while maintaining high durability and damage tolerance. The solvent sensitivity of a thermoplastic polymer (polysulfone) has been markedly reduced by the incorporation of acetylene end caps to control chain length and provide some cross-linking. The slightly cross-linked thermoplastic retains the processibility and fracture toughness of the polysulfone but is much more resistant to high temperature creep.

In the aeroelasticity program, tests of a half-scale model of a forward swept wing have shown that the wing bending motion can couple adversely with rigid-body pitching motions. Although such a flutter mode was predicted by present theory, the location of the predicted flutter boundary was not accurately forecast.

A new nondestructive method for measuring residual stress in a metal has been demonstrated qualitatively. The technique measures the small (parts in a million) shift in acoustic phase velocity which accompanies changes in magnetic properties which can be related to the stress state in the material. Noise transmission losses for large unstiffened composite panels have been measured over a wide frequency range. Remarkably good agreement with predictions was obtained. The theory must now be extended to stiffened panels.

In fiscal year 1985 research on high-temperature engine materials will emphasize improved durability and reliability of ceramics, thermal barrier coatings for metal turbine blades, and tough, high-temperature polymers. The research effort on the conservation of strategic materials will focus on developing new high-temperature materials such as intermetallics to replace superalloys requiring substantial amounts of cobalt, tantalum, and chromium. The development of new advanced powder aluminum alloys will concentrate on ligthweight alloys with increased modulus and higher temperature capability for more efficient airframes.

In engine structures and dynamics, the activity will emphasize the aeroelastic response of highly swept and twisted turboprop blades. Analysis will be expanded to include transonic and three-dimensional flow effects and the interaction between the turboprop engine system and the airframe. The relationship between parameters measured under constant temperature conditions and the parameters affecting fatigue crack initiation and growth in turbine engines will be developed. Fatigue of structural alloys will concentrate on microstructural effects on crack initiation and the growth of small cracks.

Research on composite materials will continue to place high emphasis on the toughness and durability of highly loaded structures. Studies in FY 1985 will concentrate on the micromechanics of load transfer and failure propagation in a laminate. These will be used to define the resin-fiber attributes that contribute to laminate toughness. Research on structural concepts that provide damage tolerance and fail-safe capability will continue. The principal effort will address the structural performance of stiffened curved panels for fuselage applications.

The dynamics and aeroelasticity program will continue to emphasize the development of improved analytical tools for predicting unsteady aerodynamic pressures, particularly in the transonic speed range, and the aeroelastic response of wings and turbine engine blades. Analysis methods will be verified through systematic tests of both idealized and true-scale airfoils and will concentrate on nonlinear three-dimensional flow effects. This effort will provide the basis for active control of aeroelastic response.

Data from the full-scale crash test of an instrumented Boeing 720 transport aircraft conducted in FY 1984 will be used to verify nonlinear dynamic analysis methods for large aircraft. This program is a joint NASA/FAA effort investigating structural dynamics and antimisting fuels in an actual crash environment. Future emphasis will be placed on the crash dynamic behavior of composite structural elements in simple, built-up components representing fuselage structure.

In the area of integrated analysis and optimization, efforts will concentrate on further development of the multilevel optimization method. The scope of the anlysis will be expanded by increasing the number of global optimization parameters that can be considered in a tractable solution.

*Controls and guidance research and technology*

The objectives of the aircraft and guidance research and technology program are to: (1) develop handling qualities criteria and integrated control law analysis methods for extending the performance envelope and reliability of highly augmented future civil and military aircraft; (2) develop architectures for flight crucial systems for future aircraft and devise analytical methods and techniques for assessing the reliability and performance of complex intergrated fault-tolerant flight control systems; and (3) investigate emerging control and guidance technologies which offer future alternative approaches for continued aviation safety and efficiency. Major program elements are: applied control theory, architectural concepts, system assessment methods, environmental effects research, and flight path guidance.

Applied control theory research is a major element in the controls and guidance program, and excellent progress has been made in developing and evaluating monlinear inverse control system concepts. These concepts were tested on a UH–1H helicopter, and the envelope of operation was expanded close to the aircraft's performance capability. Also, as part of a joint cooperative program with the British Royal Aircraft Establishment, nonlinear control laws were developed and tested on the NASA F–8 digital fly-by-wire aircraft. These control laws provided improved handling qualities over the F–8 stability augmentation system.

Significant progress has been made in flight crucial systems resarch. In April of 1983 the Avionics Integration Research Laboratory (AIRLAB) facility at Langley Research Center became operational. This facility is being used in the assessment and validation of flight crucial systems for aircraft and spacecraft. The engineering models of two pioneering fault-tolerant computers, fault-tolerant multiprocessor (FTMP) and the software implemented fault-tolerant (SIFT) computer, are currently being evaluated in AIRLAB. CARE III, the computer-aided reliability estimation program, and an important analytical tool for assessing the reliability of fault-tolerant systems, has been developed and used to assess the reliabiltity of the controll system for the X–29A forward swept wing aircraft. CARE III is now operational in AIRLAB and is being used to evaluate SIFT and FTMP. Concern with the effect of lightning on digital electronics has led to increased research activity both in understanding lightning phenomena and in developing protection techniques. The effectiveness of protection schemes is being evaluated using induced voltage characteristics determined from analysis of flight data. Other activities in this area have resulted in a system for random injection of lightning-induced upset transients into microprocessors to characterize the effects. A program in generic fault-tolerant avionics was initiated in 1983 to develop an advanced information processing system which includes design methodology, assessment tools, and validation processes that will satisfy

the most common set of requirements for selected aircraft and space missions.

Flight path guidance algorithms have been developed for jet transport aircraft of control aircraft approach in four dimensions (4–D) (3 spatial dimensions plus a time schedule). Also, the problems of mixing 4–D equipped and unequipped aircraft in the terminal area have been investigated. The results indicate a substantial reduction in workload and an increase in orderliness when more than 25 percent of the aircraft are 4–D equipped.

In the applied control theory area, the research effort will increase in defining handling qualities criteria for superaugmented aircraft. Also, research will continue in developing tools and design guidelines for full-authority flight control systems and the validation of these designs. This research will provide a data base which includes flying qualities, control power requirements, and design considerations for the design and test flight control system where aircraft weight and natural stability can be traded for performance, and the aircraft becomes totally dependent on the flight control system.

In the flight crucial controls area, advanced fault-tolerant architectures are being defined for application to future aircraft. These and other architectures will be assessed and validated in AIRLAB.

The architectures are derived from the assessment of the engineering of fault-tolerant computers, SIFT and FTMP, and from specific system studies such as the integrated flight and propulsion control system architectural study. To demonstrate the reliability of these systems, research will continue on validation methodology through a series of grants at several key universities with principal investigators performing research in AIRLAB. A strong emphasis remains on the development and assessment of fault-tolerant software. In the environmental effects area, emphasis will be placed on the design of digital system concepts to protect aircraft systems from upsets caused by lighting strikes. In the propulsion controls area, the principles of nonlinear robust control theories are continuing to be adapted or developed to the real-world problem of propulsion control, including control laws to accommodate failures. Fault-tolerant systems architecture for electronic propulsion controllers are also being developed along with sensor redundancy management algorithms. These concepts will be evaluated in a full-scale engine test facility. In the area of guidance concepts, energy management and full, conservative, 4–D concepts are being developed including onboard trajectory synthesis and trajectory control. The algorithms will be evaluated in an air traffic control system simulation which involves interactive participation of both pilots and FAA controllers. Research will continue on redundant sensor and actuator concepts.

*Human factor research and technology*

The objective of the human factors research and technology program is to provide a technology base for the solution of human problems which impede the growth and safety of aviation. This is accomplished by developing a fundamental understanding of the capabilities, limitations and tendencies of aircrew members in interacting with each other, with cockpit systems, and with the air

traffic control system. There are four areas of emphasis in the human factors research program: flight management, aviation safety, simulation technology, and research methods.

The flight management research program has continued to develop a basic understanding of information transfer, decision-making and resource management in the cockpit in order to provide a data base for improved cockpit systems and operational procedures. In this area, research on cockpit display of traffic information (CDTI) is continuing in cooperation with the FAA. In FY 1983, simulation studies of the interaction between CDTI and collision avoidance systems (CAS) showed that the availability of traffic information in the cockpit allows pilots to make small timely maneuvers which reduce the number of collision avoidance system alarms. Another series of simulation studies demonstrated that air carrier pilots using head-up displays (HUD) can safely reduce separation in low visibility approaches. Other flight management research is focused on developing cockpit function allocation stategies which make maximum use of automation technology in view of human capabilities and limitations. During the past year, a field study was completed on the effect of increased cockpit automation in such aircraft as the DC–9–80 and the 767 on aircrews. In addition, a human-computer interaction laboratory was developed which will be used to test hypotheses developed in the field study.

Simulation technology research is aimed at increasing the degree to which man-in-the-loop simulation can replace actual aircraft flight time in research, development, and training. Work is continuing on improving simulation of weather hazards, modeling of human perception, and the use of simulation for assessing crew performance. A recent accomplishment in weather hazard modeling is the development of a 3–D windshear model based on actual windshear data. In the human perception area, a model of monochromatic human vision has been developed which will serve as a tool in determining minimum requirements for simulator visual systems and for electronic cockpit displays.

The goal of the aviation safety research program is to identify the physical, psychological and procedural aspects of the aviation environment which tend to induce human error. The two major projects in this area are the Aviation Safety Reporting System (ASRS) which NASA is continuing to manage for the FAA, and a joint NASA/Army/Air Force program to assess the effects of fatigue and circadian desynchronosis on aircrew performance. A review of existing knowledge on fatigue has been completed, and a field study using short-haul crews has been undertaken.

The goal of the research methods area is to develop crew workload and performance methods which can aid in assessing the relative merits of alternative man/machine interface designs. In FY 1983, a method of generating simulation scenarios that impose predictable levels of imposed pilot workload has been developed which will serve as a standard for evaluating workload measures.

Flight management research will continue to encompass CDTI and the human implications of increased cockpit automation. The CDTI program will change focus from part task simulation studies to full mission scenarios as the DC–9 simulator becomes available in 1984. Also, a generic look will be taken at the perceptual aspects

of electronic cockpit displays which include not only traffic, but also weather, terrain map, aircraft pathway, etc. The cockpit automation research program will increase in scope and will encompass basic research on the interaction between crews and advanced cockpit information input/output systems such as multifunction programmable keyboards and touch-sensitive flat panel displays. It will focus on the use of artificial intelligence in alerting and warning systems, and in the use of multiple graphic windows in electronic displays.

In simulation technology, the windshear model will be evaluated and refined. An evaluation will be made of an aerosol fog generator for simulation visual systems, and guidelines will be developed for simulation of reduced visibility conditions. Research will continue on improving the capability to simulate weather hazards. A physiological measure of brain activity, called evoked potential, will be investigated as a method of evaluating the psychological fidelity of simulation to the human subject. Fundamental research on how the visual perceives computer-generated imagery will focus on developing methods for minimizing graphic distortion and misperception of information. The human vision model will be extended to include the effects of visual eccentricity and visual motion.

In the area of aviation safety, both the fatigue study and the ASRS will continue. The fatigue and circadian desynchronosis study will expand to include crews on long-haul flights. Simulation studies of long- and short-haul flights will be undertaken to test the effects of fatigue on crew performance in emergency situations.

The research methods area will continue to emphasize workload measurement research. The focus will evolve from investigation of the components of the subjective workload phenomenon to the development of guidelines for the use of workload metrics for various applications. The guidelines will be ready in FY 1985.

*Multidisciplinary research*

The objective of the multidisciplinary research program is to conduct novel, long-term, innovative research of a multidisciplinary nature related to aeronautics. This research is conducted principally at universities through the following three programs: (1) graduate program in aeronautics, (2) joint university institutes, and (3) the computational fluid dynamics (CFD) training program.

The graduate program in aeronautics sponsors graduate training and research that is relevant and acceptable to both NASA and the university in the field of aeronautics, encourages a greater number of newly graduating U.S. citizen engineers to pursue graduate training, and provides excellent interaction among students, faculty, and NASA researches in the conduct of research.

The joint university institutes program provides a core level of funding for the promotion of an active NASA/university interchange in certain key areas in order to maintain cooperative, innovative, venture research at the leading edge of the latest technology. Current elements include the joint Institute for Advancement of Flight Sciences (JIAFS), the Joint Institute for Aeronautical Propulsion and Power (JIAPP), and the Joint Institute for Aeronautics and Acoustics (JIAA) located at Langley Research Center, Lewis Research Center, and Ames Research Center, respectively.

The CFD training program provides for the development of interdepartmental university curricula and sponsors graduate training in computational fluid dynamics in response to the rapidly escalating need for specialists by NASA, the Department of Defense (DOD) and the aerospace industry.

The research and graduate student support sponsored under this activity will continue to address long-range innovative research related to the field of aeronautics and simultaneously insure a source of well trained students by means of strong interaction among students, faculty, and NASA center personnel. In FY 1985, the program will include dedicated funds to sponsor grants in the science, engineering, and interdisciplinary departments of historically black colleges and universities in order to enable the monority community to affect and contribute to the future scientific and engineering manpower pool in NASA, DOD, and the national aerospace industry.

*Computer science and applications research and technology*

The objective of the computer science and applications program is to develop an understanding of the fundamental principles underlying aerospace computing and the relationship and tradeoffs between algorithms and computing architectures, and to apply this fundamental insight in order to advance computational concepts and improve system architectures. The program supports work in concurrent processing, highly reliable cost-effective computing, information management, computer applications, and large-scale scientific computational facilities.

Concurrent processing research addresses system architectures and algorithms for computationally intensive problems in aeronautics, such as computational fluid dynamics (CFD), computational chemistry, and structural dynamics. In 1983, the new Research Institute for Advanced Computer Science (RIACS) opened, establishing as its research theme the use of knowledge-based systems to solve problems requiring massively parallel computation. In related research, representative computational chemistry codes were mapped onto alternative supercomputer architectures to perform evaluation studies through simulation at the instruction level. Extensions to the FORTRAN language were also defined to support concurrency, and a precompiler was designed to implement these extensions. A preliminary design was completed for an innovative data flow computer architecture tailored to CFD applications, and the prototype version of a multiprocessing operating system supporting the Path Pascal concurrent programming language was demonstrated in a single processor configuration.

Research on highly reliable, cost-effective computing focuses on the technology underlying the construction of systems for manrated flight vehicles. The emphasis is on investigations of software fault tolerance and cost-effective tools and techniques for developing verifiably correct software. An evaluation of the DOD high-order language, ADA, was initiated, addressing the language's applicability to distributed fault-tolerant aerospace systems. An agreement was negotiated with the DOD to cooperate on the Software Technology for Adaptable, Reliable Systems (STARS) pro-

gram, and an experimental software environment was developed to conduct software failure experiments in the AIRLAB facility.

Research in information management is addressing improved 3-D raster graphics display software for engineering applications. Work has begun on developing extensions to high-level programming languages to support graphical data types, hierarchical object modeling, and user interaction operations.

The objective of the research in computer applications is to exploit advances in computing technology to the benefit of aeronautics. Current emphasis is on the engineering design and analysis process. The integrated program for aerospace vehicle design (IPAD) is a joint NASA/Navy program to improve productivity through development of technology for the management of computer-aided design/computer-aided manufacturing (CAD/CAM) information. The first prototype of a project level data management system integrating geometric data with nongeometric information is being developed in fiscal year 1984. Research is also being conducted on parallel computing architectures and algorithms for finite-element structural analysis. Methods have been developed and demonstrated on experimental hardware to reduce computational times for static stress analysis by two to three orders of magnitude.

A major objective of the computer science and applications program is to provide state-of-the-art high-performance computational facilities for aerospace research. Ames Research Center has upgraded its Cray 1S to a Cray X-MP, and has acquired a Cyber 205 to provide the necessary scientific computing capability to support a broad spectrum of research efforts. Lewis Research Center continues to operate a Cray 1S-2200 computing facility. These systems provide vital computational support to researchers in fluid dynamics, chemistry, and thermal and structural analysis.

RIACS will be attaining a mature size and capability as it enters its third year of operation. The research in concurrent processing will develop promising architectural concepts to achieve 10–100 billion floating point operations per second on problems characteristic of aerospace applications, and a computer emulation testbed will be completed to evaluate and validate these architectures. A multidisciplinary set of benchmark kernel codes will be developed and published to provide computer architects with precise, modern, and complete knowledge of the needs for scientific computation. In software engineering research, a prototype software development and management support environment will be demonstrated; experimental studies of fault-tolerant computer software will be completed; and debugging tools for a distributed network operating system will be demonstrated. Experiments in information presentation will be conducted with 3-D color graphics to develop effective dynamic displays of complex analytical results for scientific and engineering computing.

In computer applications, IPAD will develop an initial CAD/CAM data management capability supporting the distribution of a unified data base over a heterogeneous network of computers. Parallel computing methods for structural analysis will be developed to address large nonlinear dynamics analyses typical of aircraft crash scenarios.

Support for the large scale computational facilities including a Cray X-MP and a Cyber 205 at Ames Research Center and a Cray-1S at Lewis Research Center will continue. An initial mass storage capability will be provided at Ames, inabling the online storage of numerical simulation data required for interactive real-time computational flow field analysis. The Lewis Cray 1S is expected to provide the computational capability required for near-term analysis of propulsion system components.

*Propulsion systems research and technology*

The objective of the propulsion systems research and technology program is to derive fundamental understanding and generic propulsion technology from component experiments for verifying the computational methods developed under the fluid and thermal physics program and from analytical and experimental research on complete propulsion systems. These technology advances will allow future improvements in propulsion system efficiency, performance capability, fuel flexibility, reliability, and durability, as well as environmental compatibility. The potential benefits of advanced propulsion system concepts will also be evaluated within these programs. Research is being performed on inlets and nozzles, fans and compressors, combustors, turbines, power transfer mechanisms, controls, engine dynamics, and intermittent combustion engines. These component subsystems and engine systems technology advances will lead to major propulsion system improvements in military and civil aircraft ranging from small missiles and general aviation aircraft to transports, rotorcraft, and high-performance military aircraft.

During 1983, performance comparisions were made between the measured values and values calculated from newly developed computer codes for several mixed compression and hypersonic inlets. Experimental data was successfully obtained for compressible flow in circular S-ducts and for incompressible flow in square S-ducts. In each case, good correlation between analytical and experimental results verified the availability of a new, working computer code.

Under fan and compressor research, dynamic pressure measurements and rapid radial traverses were taken of the flow downstream of a low-aspect-ratio fan stage operating in rotating stall. These data will provide the input to help extend computer modeling of the compressor map into the region beyond compressor stall. Such simulation will be required to permit future full authority digital control of engines over the entire engine operating range, including inadvertent stall regions. Instrumentation and test preparation for the multistage, axial compressor experimental research on stall recovery are nearing completion. An experimental program to determine, via laser velocimeter measurements, the detailed internal flow field and assess unsteadiness in the rotor shock system for a transonic fan stage was completed. These results provide a detailed understanding of the complex internal flow phenomena on which current transonic compressor design procedures are predicated.

In instrumentation, research in silicon carbide crystals appropriate for high temperature electronic devices is continuing with significant progress being made in the understanding of the crystal

forming process, and with measurements of the electrical properties of the crystals showing good results. High-temperature instrumentation will allow high-response temperature and pressure measurements in the hot section components of a gas turbine engine.

In combustor research, an evaluation of fuel property effects on performance, emissions, smoke formation, flame radiation, and liner heat flux, as well as an evaluation of advanced combustor concepts designed to provide fuel flexible operation, has been completed. Results of these evaluations will lead to better performance and more durable and reliable combustors in which both current and broader property fuels can be burned.

In turbine research, advanced instrumentation, such as temperature probes, liquid crystals, and heat flux gauges, has led to the mapping of local gas temperatures, heat transfer coefficients, and heat flux throughout the turbine blade channel. Knowledge of these conditions in the blade channel will lead to more effectively cooled turbine blades and, therefore, more durable and reliable turbine engines.

In propeller research an initial version of a propeller aeroelastic code with enhanced unsteady aerodynamics has been developed. A comparison of lifting line analysis predictions of flow-field velocities with laser doppler velocimeter measurements on a research propeller was completed. Wind tunnel tests were completed on an advanced low-speed propeller with composite blades to evaluate aeroelastic characteristics.

In power transfer research, the first phase of testing of a 500-horsepower (hp) high ratio hybrid helicopter transmission was successfully completed. The hybrid (traction/geared) concept takes advantage of the lower noise, higher efficiency and reduced weight afforded by traction drive systems in the high-speed low-torque components, where traction systems are the most effective, and uses gears in the low-speed high-torque components, where gears have been conventionally used. The high ratio hybrid concept is ideally suited for helicopters, since high efficiency and lightweight transmissions can be achieved while eliminating the need for separate speed reduction units currently being used in conventional helicopter transmissions.

Progress was made in several areas of research involving engine system stall recovery. The initial experimental phase of the high bypass engine stall recovery investigation was completed with results showing combustor and control involvement in the nonrecoverable stall phenomena. The results are being incorporated into the continuing effort to develop a hybrid computer model for the stall recovery characteristics of high bypass turbofans. The stall recovery effort also includes the development of stall avoidance and recovery control modes and identification of in-stall compressor characteristics using unsteady engine test data. Each of these efforts is aimed at a fundamental understanding of the stall and nonrecoverable stall phenomena in gas turbine engines leading to design philosophy and methods for avoiding the problem.

Research is continuing in optical sensors and actuators with the delivery of an optical photoswitch and 800-degree Centigrade optical temperature sensor that will allow initial experiments to be

conducted in the Lewis Research Center's fiber optics laboratory. Fiber optics for engine control system sensors and actuators will reduce system weight, increase control system speed, and reduce its susceptibility to outside electromagnetic interference such as lightning.

In the intermittent combustion engine research program, in-house basic research was initiated in rotary and piston stratified charge combustion for multifuel capability, and work was continued on a two-dimensional rotary airflow modeling code, resulting in the first computer-generated movies of flow conditions inside a rotary engine. This research is developing the enabling technologies for new, more efficient, more compact, and more reliable general aviation and commuter aircraft engines. The results will be a step increase in light aircraft performance and economy with similar implications for other land- or sea-based power needs.

Inlet research will continue on verification of design codes against wind tunnel data in fiscal year 1985. Acquisition of three-dimensional viscous data for axisymmetrical supersonic inlets at angle of attack will be completed. Verification experiments with specific application to finite volume Euler codes and analysis methods for multistage compressors will continue in the area of fans and compressor research. Compressor stall recovery data base and analytical code development will continue with collection of stall inception fundamental data from the large low-speed compressor rig. Research on silicon carbide technology for high-temperature electronic components will continue, and the development of technology needed for producing pressure transducers capable of making precision measurements at temperature levels up to approximately 530-degrees Centigrade will be completed. In combustor research, newer areas such as nonmetallic liners, diffuser aerodynamics, and ignition relight fuel effects will be studied. The ability to understand turbine aerodynamics and turbine cooling will be enhanced by the fabrication of a high temperature cascade rig five times actual size to permit precision measurements and by the continued development of instrumentation suitable for the hot section environment. In power transfer research, development of a 3600-hp split-torque transmission will be continued in collaboration with Army Aviation Research and Development Command. The second experimental phase of the stall recovery program on a high-bypass-ratio engine will be conducted to verify improved analytical codes and control modes for avoidance of and recovery from stall. Development of high-temperature optical temperature sensors, optically switched actuators, and portable digital real-time engine simulation capability used for control theory checkout prior to engine tests will be continued. The intermittent combustion engine research program will continue to focus on the design, construction and testing of a high-performance, rotary, multifuel test engine, and the expansion of testing with a signle-cylinder, two-stroke cycle, diesal test engine.

*Rotorcraft research and technology*

The objectives of the rotorcraft research and technology program are to provide a sound analytical capability, a high-quality experimental data base, and support for unique, national test facilities

for rotorcraft testing. Specific objectives include: (1) validated theoretical aerodynamics analysis; (2) acoustic theory for external noise; (3) a data base for complex interactional aerodynamics; (4) an understanding of man-machine problems unique to helicopters; (5) analysis and test of selected structural components; (6) the reduction of dynamic loads; (7) the prediction and alleviation of icing buildup on a rotor; and (8) development of handling qualities criteria for new or difficult operating conditions. In addition, this program provides the wind tunnel, flight test, and simulation support for in-house, DOD, FAA, and cooperative research experiments. Many efforts are jointly supported by the co-located Army laboratories. This research is complemented by projects funded by the rotorcraft systems technology program including large-scale wind tunnel models and experimental aircraft flight testing.

In the area of theoretical aerodynamics, the transonic, quasi-steady analysis was coupled to a far-wake model. Fixed-wing methods (Euler and vortex panel methods) were adopted for helicopter rotating coordinates. These developments enabled work to begin on a "quiet" rotor blade design. In experimental aerodynamics, two new X-Wing airfoil sections were tested in the 2 by 2-foot wind tunnel, and the effects of sweep and wall interference, both unique to this circulation control concept, were investigated.

In acoustics, the prediction of broadband noise to an accuracy of $\pm 3$ dB was demonstrated. Modeling of blade/vortex interaction continued with analysis development and a carefully conducted experiment with synchronized pressure and acoustic measurements. Laser velocimeter measurements mapped the complex vortex formation behind a fixed, twisted rotor blade to analyze noise sources. Further work was delayed by wind tunnel rehabilitation on high-priority DOD testing. Work on transmission noise was begun. A complete survey of the Langley 4 by 7-meter wind tunnel was conducted to assess its potential for highly accurate helicopter noise testing. The survey report is being discussed with the helicopter industry to establish the feasibility of modifying this wind tunnel for high quality rotorcraft noise research. No such capability now exists in the United States.

Laser velocimeter measurements were made on the new 4-bladed model rig in hover and forward flight. The effects of the interaction with a fuselage and a wing were included in that test. Preparations for a larger scale interference test in the 40 by 80-foot wind tunnel were completed to examine main rotor-tail rotor-body aerodynamic interactions. This included a rotor hover test and isolated tail rotor tests.

In human factors, analysis of pilot system information transfer continued, forming the basis for an integrated cockpit design. In flight dynamics, simulations were conducted examining yaw control power in nap-of-the-earth flight, roll control effectiveness in terrain following flight, and time delays with varied design parameters in autorotation flight. Tilt rotor simulations for civil operation continued in cooperation with the FAA.

Structural tests and analyses were conducted of high-performance woven fabrics, the response of thin-gauge composites to ballistic impact, and the performance of various cabin subfloor concepts in crash tests. Innovative structural concepts, such as thermofoam

and thermoplastic composite materials, were developed. Flight service evaluations of composite components continued.

A new emphasis was started in rotor blade optimization, varying stiffness, planform, and weight for reduced vibration and loads. Dynamic stall analyses of oscillating airfoil tests were completed. Analytical work was initiated to support X-Wing and JVX (tilt rotor) testing in 1984.

An improved deicing boot was tested behind the CH–47 spray helicopter. Differences between icing theory and test results on rotors were resolved.

Support of the 40 by 80 by 120-foot wind tunnel upgrading continued. That work included: the design of an active control technique to alleviate ground resonance of rotor models; the development of a long range laser velocimeter for remote velocity flow measurements; and the simulation of emergency procedures in the expanded speed range.

Work on the "quiet" rotor blade will be expanded in fiscal year 1985 using fully unsteady, transonic analysis. Initial runs of the Euler and vortex panel codes will be feasible with new computer capability becoming operational. Optimized tip shapes for low noise will be examined for adverse aeroelastic properties.

Emphasis on wind tunnel testing will shift to full scale when the 40 by 80-foot test section becomes operational in 1986. A test of interactional aerodynamics will use a modern 4-bladed rotor, various body shapes, wing and a tail rotor previously tested in isolation. Each will be separately instrumented. Laser velocimeter mapping of the wake, pressure data, loads, vibration and acoustic data will be taken, combining the objectives of several previous small-scale experiments.

A UH–60 model rotor will be installed on a Rotor Systems Research Aircraft (RSRA) for complete documentation in steady and maneuvering flight. This modern rotor data base will replace one which is over 20 years old and inadequate for today's configurations and the requirements for high fidelity, detailed measurements for computer analysis.

Transmission noise will be evaluated in an instrumented test, and point sources will be identified and analyzed. Noise propagation paths will be computed, and methods for suppression identified.

Research on revolutionary rotor concepts will continue with the test of a variable camber blade and a unique hub drag concept. Individual blade pitch control will also be tested in a feasibility study of high-speed actuators. These concepts are aimed at breakthroughs in performance, vibration and loads.

In human factors, flight dynamics, and advanced control work, planning will be underway to define "superaugmented" helicopter research. This research will build upon ongoing guidance and navigation research and will examine the promise of the microelectronics revolution in the demanding environment of single-pilot, all-weather, nap-of-the-earth flight with weapon systems management. Beyond merely automating pilot tasks, the efforts will examine the need for automating executive decisions at several levels, the need for artificial intelligence, the reliability and redundancy requirements, and the control authority and flying qualities necessary for

the most demanding scenarios. This work will be conducted in conjunction with the Army's advanced rotorcraft technology integration project which will define the cockpit baseline for the proposed LHX helicopter.

New materials, specifically designed for rotorcraft, will receive increased emphasis. Specific characteristics involve high fatigue life and high inherent damping. Breakthroughs in this area may have enormous benefit for the helicopter and lead to broad, nonaviation application.

*High-performance aircraft research and technology*

The objective of the high-performance aircraft research and technology program is to generate technology advancements needed to estblishe and maintain technological superiority in high-speed aircraft and missiles, including powered-lift aircraft and vertical or short takeoff and landing capabilities (V/STOL), supersonic cruise and maneuver aircraft with conventional or short takeoff and landing characteristics, and hypersonic cruise aircraft.

In powered-lift research and technology, emphasis continues to be concentrated on analytical techniques and acquiring a data base essential for development of efficient and effective military V/STOL aircraft. Aerodynamic performance characteristics at low speed were obtained on two V/STOL models, and these tests are to continue into the supersonic speed range next year. A 0.3-scale semispan model with an ejector was recently tested for performance in the 9 by 5-foot wind tunnel. The full span model is now being fabricated and will be tested in the V/STOL tunnel for in and out of ground effects. A free-flight model of the ejector configured aircraft is also being constructed and will be tested in FY 1984 in the 30 by 60-foot wind tunnel. A Harrier YAV-8B aircraft will be acquired in FY 1984 and will be modified for flight control and performance evaluations in FY 1985.

In flight dynamics, an extensive analytical/experimental program continues in the high angle-of-attack stability, control, handling qualities, and stall/spin behavior of advanced aircraft concepts to improve the low-speed combat maneuverability and safety of high-speed aircraft. Investigations were initiated in novel and unconventional aerodynamic devices, such as thrust vectoring for enhanced pitch and yaw control and vortex flaps. In aerodynamics and propulsion integration, two advanced supersonic tactical aircraft models were completed and wind tunnel tested. A study of attainale leading-edge suction as applied to fighter-type wings was completed. Results indicate that aerodynamic performance benefits, due to maximizing leading-edge suction, are greater at flight conditions than that previously determined in the wind tunnel (large Reynolds number effects). Nonlinear full potential flow analytical methods are being developed and verified for fighter wings at supersonic maneuvering conditions. Currently, an aerodynamic technology data base for efficient weapons integration, carriage, and separation at supersonic speeds is being established. Cooperative efforts continue to be pursued with industry and DOD on high-performance military aircraft design, especially in the areas of wing design and weapons carriage.

The first phase was completed of a study to identify optimum control system architectures for highly integrated airframe and propulsion controls applicable to future high-performance aircraft utilizing two-dimensional vectoring nozzles that present multivariable coupled control system design problems. A set of experiments that exercise and validate key features of the selected architecture is being defined for the Avionics Integration Research Laboratory (AIRLAB).

Work in the supersonic aircraft integration technology program was directed at the application of emerging technologies in aerodynamics, propulsion, controls, structures and materials, to military concepts. Several concepts that synergistically integrate advanced technologies for large potential performance gains were identified. Supersonic propulsion integration research emphasis was on the design and fabrication of a variable diameter centerbody inlet and on the design and analysis of inlet concepts that will allow high angle-of-attack operation.

Mach 5 turbo/ramjet propulsion system studies have identified two promising inlet concepts of which model design and fabrication are underway. Tests of a Mach 5 liquid natural gas-fueled airplane model have been completed at supersonic speeds. Dual model subsonic/supersonic combustion was achieved with high levels of net thrust and without inlet-combustor interaction. Hypersonic airbreather missile concepts are under study for potential future Navy and Air Force mission requirements in order to provide a focus for NASA hypersonic research in aerodynamics, propulsion, and structures.

In powered lift, the critical technology areas that are being investigated are in ejector performance and vectored thrust, both in and out of ground effects. The specific program is directed at achieving an understanding of the factors that influence ejector system performance.

Flight dynamic activities will emphasize three areas of concern to future tactical military aircraft: analyses of nonlinear high-altitude, high angle-of-attack flight characteristics, stall departure/spin behavior, and improved high angle-of-attack combat maneuverability. Piloted simulation studies to define control system effectiveness and requirements for advanced configurations utilizing thrust vectoring for pitch and yaw control and for integration of vortex flaps into the control system will be conducted. Also, piloted simulation of thrust vectoring throughout the flight envelope will be applied to short takeoff and landing (STOL) and short takeoff and vertical landing (STOVL) concepts.

Aerodynamics and propulsion integration research will emphasize STOL and STOVL, sustained supersonic operation, and long-range missle concepts. The vectored-thrust, two-dimensional nozzle program will include analytical efforts addressing internal aerodynamics, heat transfer and materials, and improved hot section testing capability. This activity will also include tests on full-scale nozzles.

Advanced controls research will include component technology and subsystem interactions. Digital airframe and engine controls for aircraft with vectored thrust and reduced stability are also under study.

In the area of supersonic cruise, research will concentrate on configuration development and technology integration tradeoff studies for competitive vehicle concepts. Specific areas of interest include arrow and curved leading-edge wing configurations, transonic interference effects and high angle-of-attack performance. Testing will be initiated on the variable diameter centerbody inlet wind tunnel model.

Hypersonic vehicle activities are focusing on two applications with concurrent technology development. For the Mach 5 cruise vehicle with the dual engine propulsion system, research activities include variable geometry inlets, various geometry nozzles, and hot structures for nacelle construction. Buildup of the hypersonic dual-mode scramjet test module will also be completed. The space research program will include an evaluation of a high lift/drag (L/D) entry research vehicle which could provide aeronautical performance data in this flight regime.

Flight research operations support in FY 1985 will include chase operations, airspeed calibration pacer flights, remotely piloted research vehicle air drops, and flight crew readiness operations. High-speed wind tunnel operations will continue to generate extensive experimental data for a range of vehicle configurations with emphasis on high-performance military aircraft.

*Subsonic aircraft research and technology*

The objectives of the subsonic aircraft research and technology program are to provide the necessary research and technology development for an improved and validated base of new technology for application by industry to future generations of the entire spectrum of civil/military aircraft. The program is organized into the following major categories: (1) aviation safety, (2) flight dynamics, (3) advanced transport operating systems, (4) configuration/propulsion airframe integration, (5) transport aircraft laminar flow, (6) systems analysis and integration studies, and (7) research airport support. The activities within this program encompass advanced engineering techniques and the demonstration of the feasibility of concepts to ensure rapid application of promising new technology essential to meeting one or more of the following goals: (1) defining the environment in which future systems will operate, (2) understanding the interaction of the system or subsystems with the environment, (3) developing advanced technology interaction of the system or subsystems with the environment, (4) developing advanced technology within the system itself, and (5) extending the capabilities of man in the system.

The objective of the aviation safety program is to provide a better understanding of aeronautical safety hazards and their consequences and to improve criteria for design of aircraft systems and operating techniques. It involves research in aviation meteorology, aviation operations safety technology, and aircraft systems operating efficiency improvement.

The objective of the flight dynamics program is to develop a better understanding of basic phenomena, improved analytical and experimental techniques, new concepts, and valid experimental data relating to flight dynamics and handling qualities of small and medium-sized subsonic aircraft.

The objective of the advanced transport operating systems program is more efficient and safe transport aircraft operations in the National Airspace System via integration of airborne capabilities with the evolving system; reduced individual aircraft costs through improved operations and reduced system complexity; and improved man-machine interface.

The objective of the configuration/propulsion airframe integration program is to reduce integration losses that are associated with integrating propulsion systems with the airframe.

The objective of the transport aircraft laminar flow program is to develop technology for application to future commercial transport aircraft. Elements of the program involve evaluation of laminar flow concepts including natural, hybrid and full laminar flow control; establishment of a design data base; and evaluation of the practicality of this technology.

The objective of systems analysis and integration studies is to provide a stable ongoing effort in the exploration of the potential benefits and advantages derived from the integration of advances in individual aeronautical disciplines into whole configuration concepts.

The objective of the research airport support program is to provide and operations of the research airport and other supporting services at the Wallops Flight Facility for aeronautical research and technology in those areas dealing with flight characteristics and performance and related aircraft systems.

In FY 1985 the aviation safety program will focus on expanding aircraft icing research into a cooperative broad-based National Aeronautics and Space Administration/Federal Aviation Administration/Department of Defense/National Oceanic and Atmospheric Administration program. The program will apply ongoing meteorology hazards research in simulation technology for research in human factors displays, aerodynamics, training, safe and efficient flight planning, instrumented aircraft participation in the interagency mesoscale meteorology field research program, and improving aircraft operations on nonstandard runway surfaces. The final phase of the cabin fire safety program will be completed with full-scale testing by FAA of large, lower weight fire-resistant wall and ceiling panels. The results of the full-scale controlled aircraft impact demonstration will be analyzed for validating structural impact dynamic computer codes.

In the flight dynamics area, emphasis will be directed toward cooperative activities with general aviation aircraft manufacturers to investigate the applicability of spin-resistant concepts and advanced aerodynamics for future aircraft designs. Both single- and multi-engine configurations will be considered. The implications of advanced flight dynamics technology on small aircraft certification standards will be developed and made available to the FAA.

In advanced transport operating systems, the program direction will be on air traffic control/aircraft system simulation studies, the establishment of airborne systems performance baseline, crew roles and procedures concepts, and specific airborne function concepts. Activities will include validation of a total energy control system, runway friction tests, microwave landing system transition techniques, advanced electronic attitude director formats, high speed

runway turnoff guidance system and display evaluations, and integrated flow management concept studies.

In the configuration/propulsion airframe integration area emphasis will continue to focus on enhanced aerodynamic performance of new configuration concepts. Concepts for general aviation, commuter aircraft and large transports to minimize aerodynamic drag penalties associated with integrating the propulsion systems will be addressed.

The transport aircraft laminar flow program will involve completion of the demonstration of the effectiveness and practicality of wing leading-edge systems in maintaining laminar flow under representative flight conditions, establishing a flight data base for hybrid laminar flow control and natural laminar flow transition analyses/designs, and completion of design and evaluation of integral and glove surface panel structural concepts.

Systems analysis and integration studies will include further detailed investigation of the potential benefits and research needs related to advanced electric secondary power systems for large transports. This is a NASA-developed concept which evolved from space technology research. It will be investigated cooperatively with aircraft manufacturers to refine recently completed in-house studies and to delineate major areas requiring further research.

SYSTEMS TECHNOLOGY PROGRAMS

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Rotorcraft systems technology | $26,500,000 |
| High-performance aircraft systems technology | 21,000,000 |
| Subsonic aircraft systems technology | 19,000,000 |
| Advanced propulsion systems technology | 26,100,000 |
| Numerical aerodynamic simulation | 26,500,000 |
| Total | 119,100,000 |

*Rotorcraft systems technology*

The rotorcraft systems technology program conducts research on two fronts. The first thrust consists of efforts in broad systems technology areas that advance the state of the art in flight dynamics and controls, aerodynamic analyses, and the prediction and reduction of loads, vibration and noise. The second thrust involves advanced military and civil concepts which are investigated in conjunction with DOD and the FAA. These currently include the X-Wing demonstration test on the RSRA, and XV-15 tilt rotor flight testing. In both of these thrusts, integrated system testing is required and involves large-scale wind tunnel testing, flight testing and moving-base simulation.

The guidance and navigation research has been well integrated with the FAA. For remote site IFR (Instrument Flight Rules) approaches, a simulation of a high-resolution radar for limited visibility landings was conducted. The use of low-cost beacons and airborne radar for all-weather guidance was investigated. Curved-path flight tests using a flight director in an MLS (microwave landing system) environment were conducted. The simulation of an existing digital automated avionics system newly adopted to helicopter

needs was initiated. In FY 1985 the primary elements of this effort will be continued in the research and technology base.

Flight dynamics research is well integrated with the Army in its co-located Aeromechanics Laboratory. A sling load operation under a CH-47 was simulated. Anaylsis of two helicopters (twin lift) supporting a single load was undertaken. Simulation of fault-tolerant control architectures was begun to study failure modes and system requirements. A study of fault-tolerant actuators was completed.

A variety of large-scale rotors have undergone only limited testing since the 40 by 80 by 120-foot wind tunnel upgrade is not yet complete. A modern 4-blade rotor has been procured for the interactional aerodynamics testing described under the research and technology base program. Instrumentation of an existing rotor was completed for a test of vibration suppression using multicyclic control of blade pitch. The failure of the bearingless main rotor (tested in a hover in 1983) was diagnosed. Preparations have begun to test an advanced French rotor in 1986. In return for the use of NASA facilities, the French have agreed to make available the aerodynamic and structural design details for use by U.S. industry.

In 1984 the two RSRA aircraft were used to support the joint NASA program with DARPA to demonstrate the X-Wing rotor in flight. One RSRA was modified by the contractor to accept the X-Wing rotor. Simulations of the X-Wing/RSRA were conducted in the Vertical Motion Simulator (VMS) for transition, conversion and emergency operation. The second RSRA was tested at Dryden Flight Research Facility in a fixed-wing mode with it rotor removed to simulate various X-Wing conditions. Following this test, the vehicle resumed its original test program, completing documentation of the five-bladed S-61 rotor. For new testing to begin in FY 1985, a modern four-blade rotor was acquired for acoustic and aerodynamic investigation. This effort will be continued in the research and technology base in FY 1985.

Tests on the XV-15 tilt rotor research aircraft resumed with the installation of new, stronger hubs. This enabled the XV-15 to complete portions of the flight envelope documentation previously limited by hub loads. The advanced technology blades were hover tested on the outdoor aerodynamics research facility together with an XV-15 rotor and a conceptual JVX (joint armed services vertical take-off aircraft) rotor. The advanced blades were installed on the XV-15 in preparation for flight testing. JVX simulations were supported with the construction of a special cab for the VMS.

In propulsion systems, ground testing of the convertible fan/shaft engine continued. This modified TF-34 engine is establishing a data base for propulsion concepts for high-speed compound helicopters such as the X-Wing.

Rotorcraft systems studies continued, highlighting new opportunities for research. In 1984 several pilot projects were completed in applying fixed-wing optimization techniques to helicopter problems. NASA participated in a study and conference on future air transportation for the State of Alaska. Also sponsored were contracts that identified the technology needs of public service helicopters such as emergency medical service vehicles. Several advanced DOD vehicles were conceptionally designed (LHX/Army light helicopter, JVX/tilt rotor, X-Wing).

In flight dynamics research, Army field pilots will verify the simulation of sling loads, with areas for improvement to be identified. Simulation of twin lift will be accomplished, establishing its feasibility as a piloted task. Fault-tolerant control work will continue in the laboratory with the manufacture of several experimental fault-tolerant actuators. Flight dynamics and human factors research will also be involved in the "superaugmented" rotorcraft studies.

With the delay of 40 by 80 by 120-foot wind tunnel operation until FY 1986, a large backlog of tests will accumulate. The interactional aerodynamics test which seeks to examine main rotor/fuselage/tail rotor/wing interference and noise and loads measurements will continue in the preparation stage. Also undergoing preparation will be the test of multicyclic control for vibration suppression to investigate various control algorithms in order to document the promise of adaptive control theories for the first time. Arrangements for the French rotor test and a reconstructed bearingless main rotor to be tested in 1986 will continue. A UH-60 rotor will be instrumented for comprehensive noise testing in 1986.

The advanced technology tilt rotor blades will be tested on the XV-15. This will conclude the NASA flight test program of this very successful research aircraft. One vehicle may go to the Navy in support of the JVX full-scale development. A JVX rotor/wing combination will be tested in the 40 by 80-foot wind tunnel as a critical milestone in that program. It will be the first test in that facility when it becomes operational in FY 1986. Simulation support will also continue.

The X-Wing rotor program will be generating wind tunnel, simulation, and analytical data. This fast-paced program culminates in several crucial tests in 1985 and will require special NASA capabilities to support the contractor's efforts. In particular, a model rotor test will be supported for detailed aeroelastic behavior in helicopter transition, conversion and stopped rotor flight modes. The first demonstration flight of the X-Wing rotor concept is expected in 1985.

*High-performance aircraft systems technology*

The objective of the high-performance aircraft systems technology program is to generate validated engineering methods and design data applicable to the development of advanced high-performance, high-speed aircraft for military and civil applications. The program objective is accomplished by analysis, ground-based simulations, and wind tunnel experimental research and flight research test of aircraft, as well as development of specific analytical methods for turbine engine durability improvements.

In the joint NASA/Air Force Advanced Fighter Technology Integration (AFTI) program, the AFTI/F-16 digital flight control system phase was completed, and the aircraft is undergoing modification for the automated maneuvering attack system flight phase scheduled for FY 1984. In the AFTI/F-111 Mission Adaptive Wing project, the modified wing was delivered by the contractor (Boeing) to NASA for installation in the F-111 aircraft. After final assembly and checkout is completed, the aircraft will undergo flight testing scheduled for mid-FY 1984. The joint NASA/Navy program to improve the high angle-of-attack flight characteristics of the F-14 was

completed after extensive evaluations of the NASA-conceived aileron-to-rudder interconnect control system was shown to be effective in the high angle-of-attack flight region. After successfully completing the flight evaluations of the digital electronic engine control (DEEC) program, the F-15 aircraft will be used this year to continue propulsion system improvement flight investigations using an F-100 engine model derivation with the DEEC system to address failure detection and accommodation. In the NASA/DARPA X-29A forward-swept-wing flight demonstration program, NASA is continuing to conduct wind tunnel tests, simulations, computational analysis, and ground tests in preparation for the flight test phase scheduled for initiation in FY 1984. The highly maneuverable aircraft technology (HiMAT) program, after successfully demonstrating its vehicle design goals, was completed. Results from the flight tests are being analyzed and reported. An F-4C aircraft will be modified with spanwise nozzles located over the wing leading-edge root and near the tip to verify in flight the low-speed flying qualities improvements predicted by analytical and wind tunnel tests. In the powered-lift research and technology program, a YAV-8B Harrier will be acquired and modified in FY 1984 for flight control and performance evaluation studies.

In FY 1984, the turbine engine hot section technology (HOST) program continues to address the technical issues involved in engine durability. A 3-D thermal-structural data transfer module was developed and released to industry. Advanced turbine engine instrumentation was demonstrated with the development of an improved hot section viewing system and a high-resolution dynamic gas temperature probe. An assessment of existing combustor aerothermal models led to the realization that major improvements and new benchmark tests are required. A new test facility for combustor lines cyclic testing has been put in place at Lewis Research Center. Also, major improvements in the fatigue laboratory have been completed, allowing complex computer-controlled thermomechanical loading of turbine alloys and coatings.

The FY 1985 funding level reflects an increased emphasis on high-performance flight research to provide the technology foundation applicable to the development of future high-performance aircraft. The high-performance flight research activity in FY 1985 will involve a variety of high-performance aircraft to investigate advanced concepts. Several projects will continue their flight test phases during this period. Under the joint NASA/Air Force AFTI projects, the F-16 aircraft will continue flight evaluation of integrated technologies comprising the automatic maneuvering and attack system (AMAS), and the F-111 mission adaptive wing will continue flight envelope expansion starting with the preliminary assessment of the automatic flight control system (AFSC). The joint NASA/DARPA X-29A forward swept wing flight demonstration program will continue its envelope expansion and begin its flight research phase of the program. The F-15 highly integrated digital electronic controls (HIDEC) program will begin flight research to evaluate the potential of improving the performance and mission effectiveness due to engine-airframe control integration. The high angle-of-attack flight research activity will be continued using other aircraft opportunities and will focus on developing the design

methodology applicable to handling qualities improvement and control system design for aircraft operation at high angles of attack. In FY 1985, the YAV-8B Harrier program will concentrate on evaluation of the performance of the NASA-modified flight control system for comparison with simulations.

In FY 1985, the HOST program will concentrate on continued improvements in instrumentation to validate newly developed models; studies on multiple jet dilution mixing and flame radiation/heat flux modeling; and 3-D flow and heat transfer models for nonrotating and rotating components, including cooling passage effect. Advanced 3-D inelastic structural/stress analysis methods and solution strategies will be developed, along with anisotrophic life/constitutive models for creep-fatigue interaction. Also, the role of oxide scale and costing composition in hot corrosion will be evaluated. the research program on the use of ceramic materials for long-life components will continue.

*Subsonic aircraft systems technology*

The objective of the subsonic aircraft systems technology program is to provide a substantiated base of key technologies, design data and validated design procedures. Individual concepts are examined in the systems context with other interacting components and technologies to define techniques and procedures for obtaining maximum benefit from these applications.

The objective of the composite primary aircraft structures program has been to provide a technology base for graphite composite material used in secondary and medium primary aircraft structures. Technology efforts have proceeded on schedule and major milestones have been met on lightly loaded, stiffness critical, secondary and medium primary structures. Secondary composite structures are now state of the art and already in airline operational service on the Boeing 767. The FAA certified the B-737 composite horizontal stabilizer medium primary structure in August 1982, and five shipsets of this component will be installed on the B-737-300 line and will enter flight service evaluation by Delta and Alaska International Airlines in 1984. The L-1011 vertical stabilizer successfully completed all strength and damage tolerance tests, and small-scale elements have completed 20 years of simulated environment and fatigue testing. NASA will run residual strength tests on these specimens in-house. Ground tests of the DC-10 vertical stabilizer were successfully completed in 1983 with final failure occurring at 7 percent above predicted load. A flight article is being fabricated for flight test to support certification. The program on medium primary structures will be completed with the FY 1984 FAA certification of the DC-10 vertical fin.

The objective of the advanced composite structures technology program is to develop a composite primary airframe structures technology base that achieves the full potential of weight, fuel, and cost savings possible for the design of civil and military transport aircraft in the 1990's. The program's purpose is to establish a composite engineering data base which will permit government and industry management decisions to commit composites of advanced, large aircraft with acceptable cost and risk. Full airframe use of lighter weight composites in primary airframe structure can

reduce overall aircraft weight and acquisition costs by up to 15 percent, significantly lowering operational costs and extending service usage.

The FY 1985 budget estimate for the second year of the advanced composite structures technology program is based on consideration of the existing state of the art for composite structures and the technology development needed to establish the engineering data and confidence required for the application of composite primary structures to large civil and military transport aircraft in the 1990's, as well as detailed proposals to conduct this research. Research and technology efforts were initiated in three major areas: (1) wing technology development focused on critical design issues, structural criteria, and certification requirements; (2) fuselage curved panel technology considering biaxial and post-buckled loading; and (3) advanced materials with increased resistance to damage and impact loads. These efforts will provide a basic understanding of composite performance in large airframe structures and will provide design guidance in the development of acceptable configurations and procedures to evaluate limiting structural effects.

In FY 1985, continuing wing structure activity will include test evaluation of design details for structural configurations and the development of a large body of design information to support the ongoing detail structural design work. Analytical procedures will be assessed and verified with small scale element tests, and structual criteria will be defined for thick laminates, fuel containment, and damage tolerance. This research will provide the design engineering data and criteria needed to support the detail design of the major structural test components, as well as future designs of large, heavily loaded composite wing structures.

The FY 1985 effort on technology development for fuselage structures will focus on establishing design concepts identifying critical design issues, and determining damage-resistant configurations through a multitude of small-scale structural element tests. Additional work will define the limits of post-buckling behavior and will extend testing to larger curved panels under combined pressure and bending loads. These efforts will provide design approaches and engineering data on strength-critical, large curved panels to support the detail design of large test components, and establish design methods and criteria for large, thin pressure sections.

Advanced materials research and technology will develop and characterize tougher, more processable composite systems with increased resistance to flaws and induced damage. New resins will be synthesized to increase strain limits, and the fiber interface will be studied to improve bonding characteristics.

*Advanced propulsion systems technology*

The objective of the advanced propulsion systems technology program is to explore advanced concepts for future aircraft engines in high-payoff technology areas through the focusing of fundamental research and technology efforts and integration of advanced propulsion components.

The energy efficient engine program is nearly complete. The integrated core/low spool test has been completed successfullly and

the remaining component tests, which are compressor rig tests at both contractors, will be completed during 1984. All data support the goal of 15 percent fuel savings when these technologies are applied to advanced turbofan engines. Studies conducted during FY 1983 have shown that advanced component technologies beyond those developed in the energy efficient engine program have the potential to reduce fuel consumption an additional 15 percent.

Activities in the advanced turboprop systems program are focused on development of a broad research and technology data base and on support for potential future systems integration/flight research phase necessary to establish large-scale advanced turboprop feasibility. The preliminary design review for the large-scale advanced propeller (LAP), 9-foot-diameter SR–7, was conducted. The design recommended by Hamilton Standard was approved, and fabrication of the first large-scale single-rotation blade will be performed in 1984. An independent assessment of the SR–7 aerodynamic, acoustic, structural and aeroelastic characteristics is in progress at Lewis Research Center (LeRC). Detailed design of the 2-foot-diameter aeroelastic model of the SR–7 is underway and will be used to verify the aeroelastic scalability of the 9-foot LAP. The proposals for the propeller test assessment (PTA) are being evaluated, with contract award scheduled for 1984. A contract was awarded on November 22, 1983, (to the General Electric Company) to provide a counter-rotating propeller drive rig and several 2-foot-diameter propfan models to the Lewis Research Center for testing in the 8X6-foot wind tunnel. A proposal for an unducted fan engine ground test program for a gearless counter-rotation propfan concept is also in the evaluation process at LeRC with a contract award scheduled for 1984. High-speed wind tunnel aerodynamic performance investigations of the contoured over-the-wing nacelle installation on a semispan wing and low-speed wind tunnel stability and control investigation of aft-mounted configurations will continue in 1984. Subscale propeller model tests in high-speed wind tunnels and on the Jet Star aircraft have given encouraging indications of achieving cabin comfort and community noise goals with only minimal weight and configuration penalties.

The general aviation/commuter engine technology effort for 1983 and 1984 serves as a focus for small engine component research that is aimed at 25 percent improvement in small engine component efficiencies. Analytical design techniques that incorporate the small engine limitations associated with scale, surface finish and Reynolds number are being developed and verified through the use of advance instrumentation and experimental techniques. Specific efforts include the testing of centrifugal compressors scaled from 20 lb/sec to 10 lb/sec, evaluation of transpiration cooled reverse flow combustor liners, and evaluation of innovative variable area radial inflow turbines.

The broad property fuels research in 1983 emphasized the testing of combustion systems, turbines, and fuel systems in order to understand the effects of fuel property variations. The objective was to provide an understanding that would lead to fuel flexible concepts, components, and systems to help aviation adapt to envolving world energy supplies.

In FY 1985, advanced turboprop systems program activities will continue toward a flight test in 1987 and will include advanced concepts and configurations such as counter-rotation propeller systems. In FY 1985, the aeroelastic model of the large-scale propeller (SR-7A) will be fabricated, and wind tunnel aerodynamic performance investigations of improved under-the-wing and over-the-wing nacelle installations on improved semispan wings will be completed. High-speed wind tunnel stability and control investigations of wing and aft-fuselage mounted propeller configurations will be completed. High-speed investigations of wing- and aft-mounted counter-rotation propeller configurations will also be carried out. Additionally, validation tests of counter-rotation propeller model performance and acoustics will be completed.

The general aviation/commuter engine technology effort will continue to focus on the development of a fundamental understanding and analytical data base for flow phenomena and heat transfer in small gas turbine engine components. Fundamental efforts will include large low-speed rig and small high-speed 2 lb/sec centrifugal compressor flow-field measurements using laser doppler velocimeter instrumentation to provide benchmark data for size-related design variables. Emphasis will be placed on research that focuses on endwall aerodynamics and the effects of boundary-layer thickness on secondary flow fields. Research will be continued on the investigation of radial outflow combustors and advanced materials for combustor liners, as well as cooling and variable geometry concepts for cooled radial turbines.

*Numerical aerodynamic simulation*

The numerical aerodynamic simulation (NAS) program objective is to significantly augment the Nation's capabilities in computational fluid dynamics and other areas of computational physics by developing a preeminent capability for numerical simulation of aerodynamic flows. This program will provide the computational capabilities required to obtain solutions to problems which are currently intractable. Ongoing research and technology base efforts in computational aerodynamics will benefit significantly from the advanced computational capabilities to be provided by the NAS program. The combination of these programs will provide pathfinding aeronautical research for the future, allowing solutions of the full Navier-Stokes equations, providing first-principle prediction of viscous flow about simple aeronautical shapes, and enabling the prediction of performance of complete aircraft. The NAS program will develop an extensive, user friendly system to assist engineers and scientists in all aspects of problem solution, from problem formulation through graphical presentation of results. The heart of this system is the high-speed processors, which will be the most advanced commercially available supercomputers. These machines will provide the large-capacity/high-speed computational capability required in advanced fluid dynamic research and applications.

The NAS program study and planning phase was initiated in the research and technology base in FY 1983 with system development beginning in FY 1984. This phase will lead to a system design review in FY 1984 and will formalize the design of the NAS system. The system software development contractor will begin de-

velopment of the network language and protocols during FY 1984. The initiation of the full-scale development of the system software will occur after the results of the network testbed tests are analyzed. The network testbed has been assembled and testing has begun on both networking languages and protocols. These tests will be completed in FY 1984 and will result in the selection of a candidate networking language and protocol that meets the NAS system requirements. Also initiated during FY 1983 were the procurement activities leading to the acquisition of the first high-speed processor.

The first high-speed processor for the NAS system will be acquired in 1984 and will continue under lease through FY 1985 and beyond. This high-speed processor is the heart of the NAS system and the key component around which the extensive, user friendly subsystems are assembled. The development of the system control and operation software will be continued during FY 1985 leading toward an FY 1986 initial operational status for the NAS system. The NAS system network devlopment will continue with the acquisition of critical system components required to attain system operational status. The critical system components include additional work stations to provide access to the NAS system through the support processing subsystem and acquisition of components for the long-haul communications subsystem which will allow remote access to the NAS. Additionally, initial acquisition and assembly of the graphics subsystem will occur, which is required to support the output and analysis of large data-producing solutions/simulations. The combination of the work station, support processing, and graphics subsystems is critical to the successful initial operation of the NAS system. System tests and integration activities leading up to the initial NAS operations will begin in FY 1985. These tests and integration activities are necessary to assure that the NAS system meets the system requirements developed during the initial planning activities. FY 1985 will be a year of intense activities leading toward the initial operations of the NAS system in FY 1986.

### 9. SPACE RESEARCH AND TECHNOLOGY, $150,000,000

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Research and technology base | $136,000,000 |
| Systems technology programs | 9,100,000 |
| Standards and practices | 4,900,000 |
| Total | 150,000,000 |

The overall goal of the space research and technology program is to advance the technology base in support of NASA's role as an effective, productive, and long-term contributor to the continued preeminence of the United States in space. The specific objectives of this program are to support a broad-based advanced technology program designed to provide new concepts, materials, components, devices, software and subsystems for use in United States civil and military space activities; assure preeminent national capability through extensive and interrelated participation in the program by the NASA centers, other government agencies, universities, and industrial research and technology organizations; and, maintain

NASA centers in positions of recognized excellence in critical space technologies. The FY 1985 program supports these objectives by placing emphasis on disciplinary technologies that provide the necessary data base and understanding to create new opportunities for future national civil, military, and commercial space mission objectives, and on systems technology programs directed at obtaining fundamental data from in-space experimentation, and transferring advanced technology into space programs through more focused efforts that provide proof of concept to support technology readiness for anticipated applications.

The FY 1985 program in space research and technology will continue to be directed toward providing the broad base of innovative technology essential to the conduct of future space missions. It supports agency goals in space transportation systems operational effectiveness, space station concept formulation, science and applications mission capabilities, and provides synergistic support to the military and commercial space user needs.

In fluid and thermal physics, efforts will continue to improve the analytical and predictive techniques within, and the transition between, continuum and rarefied flow regimes while new emphasis will be placed on transatmospheric space flight. Materials and structures, activities will include large-area structural concept development, solar array construction techniques, generic mechanisms technology, and the combined effects of structural dynamics and controls. The computer science and electronics program will stress concurrent processing, a critical element in computational fluid physics research, and will increase emphasis and focus on optics research. Advanced sensor technologies will continue to explore laser, electro-optic and microwave concepts for both remote and in-situ applications. The space energy conversion program will continue its emphasis on high-capacity power and thermal systems required for a permanent presence in space and on technology for high specific power, low weight systems for geosynchronous and planetary missions. Electric propulsion technologies will stress auxiliary propulsion applications with continuing attention on power processors and thrusters; resistojet technology will focus on more efficient orbit maintenance concepts; and, thermal-to-electric energy conversion in support of the SP–100 nuclear reactor power system research and technology program will receive increased emphasis. Research emphasis in the controls area will be placed on large, flexible, and precisely controlled structures; the integration of attitude control and energy storage functions in flywheels; and, the precision pointing of large spacecraft. Human factors efforts will continue to be aimed at the enhancement of astronaut productivity through improved information management techniques, extravehicular work stations, and a telepresence capability. In space data and communications, increased emphasis will be placed on information systems research including automation, robotics, optical information and data systems. Chemical propulsion technology will be directed toward: the understanding of life and performance parameters for liquid oxygen-liquid hydrogen engines such as the space shuttle main engine (SSME) and other potential advanced high-pressure engine systems, stressing component and integrated diagnostic instrumentation techniques; orbital transfer engine tech-

nology to enable space-based, throttleable, and reusable systems; and, technology for gaseous oxygen-hydrogen propellant systems. When required to obtain valid research data, in-space flight experiments will be performed to support discipline or systems research programs by capitalizing on the shuttle as an economical experiment base.

Within the research and technology base, the spacecraft, transportation, and platform systems programs will continue to develop analytical tools that provide a continuing basis for planning, ranking, and identifying emerging technologies for focused transition to flight program application. The spacecraft systems efforts will emphasize development of spacecraft technology for advanced earth-orbital and planetary spacecraft. Satellite communications research and technology is directed toward long-term, relatively high-risk developments in the Ka band and at frequencies extending through the 100 gigahertz (GHz) range. In the transportation systems area, emphasis will be placed on identifying technology requirements for advanced earth-to-orbit transportation systems including improved space shuttle systems and orbital transfer systems with consideration being given to aeromaneuvering, space basing, maintainability, operational flexibility, and manned options. Efforts in the orbiter experiments program will continue to exploit the operational flights of the shuttle by installing instrumentation which provides a valuable source of flight research data. The platform systems program will be directed toward defining generic systems and advanced discipline technology efforts that support the agency thrust for permanent occupancy in space. Platform systems research and technology will establish technology for distributed data systems architecture, automated and teleoperated systems, life support systems, and operational extravehicular activities.

The advanced SSME systems technology program will focus on providing system level data for modeling performance and life, and validating component technology designed to improve life and reduce maintenance costs. The components will be installed on a testbed SSME and instrumented to provide the overall understanding and data base on performance in the realistic hot-fired engine environment. This is a joint program in which the Office of Space Flight will provide the testbed SSME.

### Research and Technology Base

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Fluid and thermal physics research and technology | $8,900,000 |
| Materials and structures research and technology | 17,400,000 |
| Computer science and electronics research and technology | 16,200,000 |
| Space energy conversion research and technology | 24,600,000 |
| Controls and human factors research and technology | 9,800,000 |
| Space data and communications research and technology | 17,800,000 |
| Chemical propulsion research and technology | 17,400,000 |
| Spacecraft systems research and technology | 9,700,000 |
| Transportation systems research and technology | 8,400,000 |
| Platform systems research and technology | 7,800,000 |
| *General reduction* | *−2,000,000* |
| Total | 136,000,000 |

*Fluid and thermal physics research and technology*

The fluid and thermal physics program has the following objectives: (1) to develop validated experimental and computational techniques for predicting flow fields for a broad range of arbitrary aerospace vehicle configurations; (2) to improve techniques for predicting aerodynamic and aerothermodynamic characteristics of vehicle concepts in the continuum-to-rarefied flow regimes; and (3) to provide the experimental technology required for aerodynamic and aerothermodynamic testing. Improved techniques for predicting the capability and response of future aerospace vehicles in the various flow regimes, including ascent to orbit, low-earth orbit, and entry, will provide increased confidence needed for maximum use of the performance and payload potential of those systems.

Progress in the ability to predict flow fields about vehicles entering the Earth's or other planetary atmospheres has been accelerated by new computational techniques capable of analyzing shuttle-like vehicles at high angles of incidence that produce locally subsonic flow over the entire lower surfaces. These predictive codes have been validated by the data returned from shuttle flights one through five. Flow over the upper surfaces of such vehicles remains difficult to calculate because of the formation of separated zones that roll up into large vortex systems. At present, empirically derived methods provide limited capability for these upper surface predictions. Study of the very high Mach number flows over entry bodies has provided new information on chemical reaction rates and radiative properties of gases which will be useful in the future development of aeroassisted orbital transfer vehicles and heatshields for spacecraft entering the atmospheres of Saturn, Jupiter, Titan, and Mars. Exploratory studies of space-based aeroassisted orbital transfer systems have identified nonequilibrium radiation as an unknown factor that may control important decisions on heatshield geometry and material.

The theory of rarefied gases has been advanced by the use of a dedicated computer especially programmed for the multibody collision processes involved. The methods developed are being used in the study of contamination of spacecraft by control jets and, also, for estimation of forces and torques acting on reentry vehicles in the initial high altitude portion of the trajectories.

The orbiter experiments program has made use of the shuttle orbiter as a research aircraft permitting the evaluation of aerodynamic prediction methods. The flight data have generally corroborated predictions over much of the flight regime; however, several situations were found in which sizable differences occurred. Of particular interest for future aeroassist maneuvers is the variability in atmospheric density that was identified during the STS flight 5 as being as large as 25 percent of the best estimates. Variations of this size could pose serious problems for the guidance and control of space-based aeroassisted orbital transfer vehicles.

Aerothermal loads research focuses on the interaction of high temperature, high Mach number flows with specific surface structure. During the past year, analytical studies were performed to predict the heating of bowed quiltlike surfaces simulating advanced thermal protection systems, and a test program was prepared for

the 8-foot high temperature structures tunnel at the Langley Research Center. The computed results show significant pockets or hot spots generated by the distorted surface. During the past year, the program supported the operation of high temperature, high Mach number facilities at the Ames and Langley Research Centers. These facilities provide a unique group of test jets and tunnels that were used extensively in the shuttle development. Also, they will be needed for all future development of advanced vehicles and for validation of the developing computational methods of vehicle design.

In FY 1985, computational methods will be advanced to treat the problems of vortex generation over upper surfaces of reentry vehicles of advanced design. Application of current prediction methods to high lift-to-drag ratio vehicles will be assessed, and approximate heating and aerodynamic force codes will be improved in accuracy and speed for use in the AVID system. The developing capability for computing rarefied gas flows will be applied to estimating the forces and torques on very large space structures, and flight test data from the shuttle will be evaluated to obtain comparisons with the theory. Ground based tests in this flow regime are not yet possible; therefore, reliance must be placed on the flight data.

Aerothermodynamic characteristics of a series of vehicle designs will be determined in a cooperative program with the Air Force. The vehicle shapes will be sufficiently different from that of the shuttle orbiters so that new problems with heating of leading edges must be addressed. Other blunt configured vehicles will be studied for use as orbital transfer spacecraft, which requires addressing new environmental conditions. In particular, the determination of the magnitude and consequences of nonequilibrium heating will continue to be a major effort in FY 1985.

The aerothermodynamic facilities at both the Ames and Langley Research Centers will be used to provide data on forces, stability and control, and control and heating for the cooperative Air Force program, and to establish a data base for use in design of orbital transfer vehicles ranging from bent conical bodies to blunt and bulbous shapes simulating inflatable and deformable heat shields.

The aerothermal loads program will attempt the development of finite element methods for solving the Navier-Stokes equations applied to high temperature and Mach number flow over advanced thermal protection materials. The finite element methods will subsequently be matched to finite element structural codes to provide a complete method for determining interaction of structure and aerodynamic heating.

*Materials and structures research and technology*

The objectives of the materials and structures research and technology program are to provide the performance, efficiency, durability, and economy required for large-area space structures, antennas and space platforms, advanced space transportation systems, orbiting spacecraft, planetary probes, and shuttle payloads. Major technical areas of emphasis in materials include basic understanding of advanced materials; development of computational chemistry methodology; characterization of long-duration environmental effects of space on materials; and the development of ceramic, metal-

lic, and advanced carbon-carbon thermal protection systems. Structures technology is directed toward development of advanced truss structural concepts; reliable methods for deployment/erection of space structures; new concepts for advance shuttle and orbital transfer vehicles; and efficient analytical methods for design and evaluation of advanced space structures, including integrated structures/thermal/controls analysis and optimization techniques.

In the past year, a highly packageable and deployable beam concept having controllable geometry was developed for use as a manipulator arm, docking device, or positioning platform. The working two-bay geodesic-truss beam model has demonstrated the potential for controllable geometry whether deployed straight, canted to the left in a C-curve, or fully retracted. A highly efficient rapid analysis capability for repetitive structure was developed and applied to an antenna-type structure. The vibration analysis of a complete complex antenna was accomplished with a repeating element of only 14 nodes at greatly decreased computation time. New analytical techniques have demonstrated the feasibility of applying heat to control the thermal distortion of orbiting spacecraft structure. Corrective temperatures, at specified control points which affect distortions, were analytically demonstrated to be an effective approach to the life-limiting problem.

Research on advanced thermal protection concepts has shown the feasibility of superalloy and oxide dispersion-strengthened materials for the hypersonic environment. Stable emittance exceeding shuttle requirements has been demonstrated in simulated reentry testing in a hypersonic arc tunnel, opening the way for more detailed structural concepts for future metallic systems. Additionally, Langley Research Center has established an advanced carbon-carbon fabrication capability to allow detailed materials characterization and the development of improved coatings for thermal protection application.

The space environmental effects facility, now in full operation, has been utilized to study the effect of combined electron and proton exposure on graphite-epoxy composities for spacecraft application. Detailed characterization of the radiation damage to these materials has shown that previous accelerated test methodology for simulated twenty-year doses produced less severe degradation than is now being seen at lower flux level/longer time tests that are possible in the new facility. Studies on the dimensional stability of graphite/aluminum metal matrix composities have shown that these new, lightweight, stiff materials appear unstable under thermal exposure when cycled between $-250$ and $+250$ degrees Fahrenheit in the unidirectional laminate layup configuration. Each cycle produces changes in specimen dimension. A recent shuttle flight experiment has significantly improved our knowledge of erosion rates in metals and ceramics due to atomic oxygen as encountered by spacecraft in low Earth orbit. The experiment also added to the basic understanding of the phenomena which can be expected to lead to a permanent solution to the problem.

The computational chemistry activity has successfully modeled the formation and growth of a fatigue crack in iron. Using a 2500 atom model, interatomic forces and dislocation theory, a prediction of fatigue crack growth rate was achieved. Plastic zone formation

was clearly evident and simulated actual experimental observations.

The effect of the space environment on structural materials for spacecraft and potential space station application will continue to be a major thrust of the program. Included in the activity will be research on the durability of polymeric materials, thermal control coatings, films, adhesives, and seals. The radiation damage mechanism in epoxy matrix composites in a simulated environment at geosynchronous Earth orbit will be identified, and methodology for accelerated testing of these materials in the combined radiation of both electrons and protons will be developed. Thermal control coatings to allow full benefit of composite structures for large-area space application will be developed. The study of the dimensional stability of such structures in the space cyclic thermal load environment will continue. Basic research in the fundamentals of tribology of bearings for spaceborne mechanisms will be carried out with particular emphasis on solid lubrication for traction-drive actuators. Advanced carbon-carbon composite thermal protection systems will continue to be a major focus in the program, with activity directed at increasing the interlaminar shear strength by approximately 50 percent, and the development of new, improved oxidation-resistant coatings. Activities in the ceramic thermal protection system area will be directed toward the further development of flexible ceramic blanket-type insulation for application to advanced orbital transfer vehicles and for further upgrade of existing material currently employed on the orbiter. Research in advanced space structures will establish structural concepts, deployment schemes, and packaging techniques that will permit planar structures on the order of 100 to 200 meters in size to be carried into orbit in one shuttle flight and automatically deployed. Additionally, erectable concepts and assembly methods for structures between 100 and 1000 meters in size will be developed. Both analytical and experimental research will be conducted to develop procedures to characterize modular structures in ground tests, as well as in orbit. Active and passive damping techniques to reduce and isolate or suppress unwanted vibration will be achieved, leading to the development and validation of methods for predicting and reducing the response of large flexible space structures. Analysis will be carried out to provide minimum-weight thermal protection systems for fully reusable advanced space transportation vehicles.

*Computer science and electronics research and technology*

The objective of the computer science and electronics program is to provide advanced concepts, techniques, system architectures, hardware components, algorithms, and software for space information systems. The program contains disciplinary activities in electronics, sensor systems, automation, and computer science. Research in electronics is directed at new lasing media and detection methods, and developing new concepts in optical and solid-state technology. Sensor research is focused on extending the capabilities of active and passive sensor systems in terms of spectral range, sensitivity, and resolution. Automation research is developing the theoretical and technological base in artifical intelligence and robotics to increase the productivity and effectiveness of future oper-

ations in space. The computer science discipline strives to improve fundamental knowledge of computing principles and to advance the state of computational technology in aerospace applications such as spacecraft operations and image processing.

In electronics, advances have been made in the physics of radiation damage in silicon devices. A preliminary design for an electronic test chip to monitor radiation damage is in the planning stage for the joint National Aeronautics and Space Administration/Department of Defense/Air Force (NASA/DOD/AF) Chemical Release and Radiation Effects Satellite (CRRES). In signal processing, an optical processor has passed initial tests, leading to real-time processing of Synthetic Aperture Radar (SAR) data. An optical receiver with a bandwidth of 500 megahertz (MHz) has been successfully tested, and experimental work is underway to increase the bandwidth by a factor of four. A well controlled tunable laser and data acquisition system have been developed for remotely sensing fluctuating temperatures and densities in high-speed turbulent wind tunnel flows. Basis research in electron-atom collision processes has resulted in the invention of a new mass spectrometer device which may have immediate application in contamination monitoring aboard the shuttle.

In sensor systems research, a prototype laser heterodyne spectrometer system was successfully fabricated and tested. A Stirling-cycle cooler with innovative magnetic bearings, designed for long-life applications in spaceborne sensor systems, completed 2,000 hours of life testing, and an experimental Joule-Thomson cycle absorption cooler, capable of lower temperatures, was built and successfully operated. Closed-cycle operation of a carbon dioxide laser radar system was demonstrated, completing a necessary step toward employing these systems in spaceborne applications. Laboratory detection of the oxygen-hydrogen (OH) radical, an important constituent of atmospheric chemistry, was demonstrated using high resolution excimer (ultraviolet) laser. A successful airborne flight demonstration of the microwave pushbroom radiometer was completed.

In automation research, the knowledge base for the Voyager spacecraft was completed, paving the way for the use of the automated planning program called DEVISER, by the Voyager project during the Uranus encounter. DEVISER, developed at the Jet Propulsion Laboratory, is recognized as the current state of the art in artificial intelligence for planning and scheduling. Experimental versions of a telemetry monitoring program and a fault diagnosis program were demonstrated, providing an early feasibility test of the engineering concepts underlying space systems autonomy. Robot sensing and control research resulted in advances in machine vision and precision control. A stereo vision system operating at a rate of 30 Hertz was successfully demonstrated in the laboratory to perform real-time tracking of a moving convex object. This system was then coupled to the control system of an industrial robot arm to demonstrate automated grappling and controlled halting of a moving simulated spacecraft. Control algorithms for precise end point control of a one degree of freedom manipulator with very low structural rigidity in the plane of motion were also devel-

oped. Each of these represents a critical step toward automated space servicing, assembly, and repair capabilities.

The computer science research program focuses on three theme areas: concurrent processing; highly reliable, cost effective computing; and scientific information management. In concurrent processing research, the first order analysis of concurrent solution methods for linear systems was completed, including both direct and iterative algorithms. Research addressing testable fault-tolerant Very Large Scale Integrated (VLSI) circuit design principles resulted in the demonstration of an initial version of a software logic and fault simulator. This system is designed to verify the fault tolerant properties of new circuit designs, and exhibited a factor of ten improvement in performance over conventional serial simulation techniques. Data base research resulted in the specification of functional architecture for a data independent access method for distributed heterogeneous data bases. In software engineering, a Software Management Laboratory was established to evaluate software measures, and a conceptual model for a software life cycle dynamic simulation and cost estimation model was developed. The Center for Aeronautics and Space Information Sciences (CASIS) ws established at Stanford University to develop a multidisciplinary academic center of excellence in aerospace computing.

Electronics research and technology development will continue to focus on submillimeter wave technology. The interaction structure of a submillimeter traveling wave tube for local oscillator applications in a heterodyne spectrometer receiver will be demonstrated. "Super-lattice" devices with material properties that are tunable will be demonstrated for application in the sensing systems technology program. Synthetic aperture radar signals with a signal-to-noise ratio of 30 dB will be processed in real time including a real-time zoom capability.

The sensors research and technology program will focus on the development of advanced lasers for space-based laser-radar systems. Development of a solid-state laser for application in spaceborne remote sensing of winds and atomospheric species will be initiated. Detector research will continue to develop and test detector arrays in the 2–200 micron range of the electromagnetic spectrum. A technology demonstration model of the Stirling-cycle cooler and a comprehensive program in microwave radiometry for large space antennas will be initiated.

In automation research, the three components comprising rudimentary autonomy (planning, monitoring, and fault diagnosis) will be integrated to demonstrate the fundamental technology of space systems autonomy. The Voyager project will be testing the DEVISER capabilities in a live mission environment, and a similar system will be undergoing test in the Kuiper Airborne Observatory in preparation for the shuttle infrared telescope facility (SIRTF) mission. The architecture of a space qualifiable knowledge-based system will be defined, paving the way for onboard applications of artificial intelligence. Robotics research will continue to advance sensing and control technology needed for robotic applications in space. Machine vision algorithms to distinguish classes of three-dimensional objects will be extended for space operations; vision algorithms suitable for VLSI implementation will be selected; and

active, compliant arm control employing force/torque feedback will be integrated into the tracking and grappling experiment, providing a testbed for designing and evaluating supervisory control techniques.

In computer science, research in concurrent solution methods and algorithms will be extended to include nonlinear discrete systems, and simulation techniques will be applied to evaluate promising computing architectures suited to these methods. In fault-tolerant circuit research, applicable techniques and approaches will be consolidated and formalized into a design methodology for testable fault-tolerant VLSI circuits, and techniques will be developed for simplification of on-chip test generation and fault diagnosis. Data base research will focus on defining, investigating, and recommending concepts and architectures for rapid update and retrieval of information contained in very large ($10^{12}$ to $10^{15}$) multisource data bases. Software engineering research will maintain close coordination with the DOD Software Technology for Adaptable, Reliable Systems (STARS) program. A full set of software design measures and a rapid prototyping environment tailored to space systems software will be developed, and parametric values for the software life cycle simulation and cost estimation model will be quantified and utilized to validate the model. CASIS, at Stanford University, will achieve its mature size and capability, performing research and educating students in concurrent processing, information management, and large-scale system architecture.

*Space energy conversion research and technology*

The objectives of this program are to: (1) increase the performance, capacity, and cost effectiveness of space electric power generation and energy storage subsystems; (2) provide the technology for efficient, reliable, and low-cost management and distribution of electrical and thermal energy for space systems; and (3) provide electric thruster system technologies for a unique national capability in electric propulsion. In FY 1983, significant advances were made in a number of technical areas. In photovoltaics, the Air Force selected the NASA-developed large silicon solar cell using wrap-around contacts and welded interconnect technology for the MILSTAR program. An important milestone in the achievement of effective concentrator solar arrays for large space systems was reached with measurement of gallium arsenide solar cell efficiency of over nineteen percent at a solar concentration of 100 suns. Nuclear reactor power offers potentially enabling benefits for future high-power civil and military space missions. To address this need, a tri-agency (Department of Defense/Department of Energy/National Aeronautics and Space Administration) effort called the SP-100 program was initiated both to advance the critical technology for such systems, and to explore mission applications. This research is expected to provide the information base for a future ground engineering system. In the electrochemistry program area, a laboratory regenerative hydrogen/oxygen fuel-cell-electrolysis subsystem was designed, fabricated and tested with highly promising initial results. Such systems are needed to reduce the mass of energy storage in large systems. Progress was also made in advancing the safety of the primary lithium battery which is becoming widely

used in spacecraft because of its superior energy density. For the first time, the chemistry of these batteries was defined during normal operation and the critical importance of impurity and material controls to avoid the generation of explosive intermediates was specified.

Under the power management program, a space test was concluded which provided insights into the power losses and arcing phenomena of solar arrays in low-Earth orbit (LEO). Understanding of this behavior is necessary to the design of power systems for future large space systems in LEO. Design guidelines for the assessment and control of charging of high-altitude spacecraft were broadly distributed for review. This step represents a major milestone in NASA's spacecraft charging programs, the output of which is already widely used by U.S. and European spacecraft designers and builders. In the area of high-power components, direct-current remote-power controllers with the capability of handling greater than fifty times the power of present devices were demonstrated. Such devices are essential in the design of large, utility type, space power systems. The laser program is aimed at providing enabling technology for civil missions in high radiation as high-drag orbits in which the conventional solar array power sources are unsuitable. The emphasis of this research is to achieve continuous lasing using sunlight and on the development of suitable receivers that would efficiently convert the laser energy to electrical or heat energy to be used for power or propulsion. Major milestones toward these goals during the last year were the achievement of continuous lasing of a carbon-dioxide laser by means of blackbody radiation and the increase in lasing time by two orders of magnitude of a solar-pumped laser. Operation of an ion thruster was demonstrated with a power processor having more than a factor of ten fewer parts than required at present. This improvement will allow significant reductions in the cost and risk of application of ion thruster systems. A simple, low-cost, and scalable heat pipe radiator concept was successfully demonstrated on a shuttle orbiter space test. This space test was the first of several which are planned to establish the technology for high-power, two-phase, thermal-rejection systems. In ground tests, the accomplishments in thermal management included demonstration of a tenfold increase in heat-pipe transport capability and successful demonstration of a long (17m) radiator heat pipe using a basic space constructible design.

Overall, FY 1985 efforts will be directed at significant improvements in both the performance and capacity of space energy conversion systems. Solar cell and array concepts with promise of a factor of two increase in efficiency and specific mass, including advanced gallium arsenide thin cells and lightweight deployment mechanisms, will be evaluated along withconcepts, such as concentrator arrays and advanced fabrication techniques, to improve the lifetime and reliability, and to reduce the cost of photovoltaic systems. Efforts will be directed at producing improved and safer lithium batteries, bipolar nickel-hydrogen batteries suitable for low-Earth orbit application, and demonstration of both alkaline and acidic regenerative hydrogen-oxygen fuel cells. In the thermal-to-electric program, efforts under the tri-agency SP-100 activity will be expanded to more fully analyze the technological, safety, and

mission related issues for the civil missions that may be benefited by use of nuclear power. Also candidate nuclear reactor systems using thermionic, thermoelectric, and dynamic conversion systems will be defined. Resistojet and arcjet electric thruster concepts will be evaluated on a variety of propellants in order to indentify designs for the control of large Earth-orbital space systems, and the lifetime of inert gas ion thruster systems will be defined by test. Guidelines for the control of charging of high-altitude spacecraft will be completed, and major emphases will be directed toward definition of the low-altitude Earth environment and its interactions with space systems. Advanced power management components, such as rotary power transformers and intercalated graphite conductors, will be studied to determine their feasibility and benefits for space power systems. In the thermal management area, effort will be focused on the technologies for two-phase systems and will include studies of fundamental fluid phenomena in zero gravity and testing of two-phase system components for thermal acquisition, transport, and rejection.

*Controls and human factors research and technology*

This program consists of two discipline areas, controls and human factors. The goal of the space controls research and technology program is to develop the design methods and techniques required to enable precise pointing and stabilization of future spacecraft. Emphasis has been placed on developing control theory and analysis and validating advanced controls and guidance concepts. Recent accomplishments include the development of new control algorithms and computer programs to simulate and identify vibrational frequencies and damping ratios of systems having multiple vibration modes, in addition to the successful demonstration of a new real-time adaptive control technique. Dynamic modeling of a reference initial and evolutionary space station has begun to characterize the dynamic behavior of the combination of rigid core modules, flexible solar arrays, deployable masts and radiators, rigid payload modules and nonrigid payloads. This effort will develop the models that will be used to test and evaluate new technologies for controlling and operating a large space system such as a space station.

The goal of the human factors program is to develop techniques, data bases and standards for the design and evaluation of man/machine interfaces for use in space operations, including ground control. This program was initiated in FY 1983. Some FY 1983 accomplishments are as follows. Teleoperator simulation facilities were developed for assessing the effects on system capability of varying visual and force feedback to the operator and of varying the amount and type of computer aiding. In the area of extra-vehicular activity (EVA) performance aids, a miniature head-up display (HUD) has been generated for mounting on a space suit helmet. A space station control room simulator has been developed, and studies of the effects of types of habitats analogous to a space station (e.g. submarines, arctic military outposts, etc.) on behavior have been initiated. Development of an algorithm for determining the types of space station tasks most appropriate for humans and for automation has been undertaken.

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Specific FY 1985 controls technology activities will include continued development of analytical techniques for onboard model error estimation which will lead to interactive structure/control design methodologies. The fault tolerance/management of sensors, actuators and related control strategies will be validated/verified in laboratory experiments. An experimental version of an advanced three-dimensional shape and orientation sensing system, which can be used to determine configuration and vibration motion of a large space structure, will be tested to characterize and determine system performance. A hierarchical structure of "levels of control" will be developed for the evolutionary space station concept. A new emphasis on the design and control of flexible structures is underway which will generate a technology data base for evaluating structure versus control design/performance criteria.

In 1985 the human factors program will continue developing technology for man/machine function allocation strategies, crew station design, teleoperators, extravehicular activity (EVA), and ground control man/machine interface. Research will be undertaken on the teleoperation simulator to assess the effect of zero gravity on pointer control of a six degree-of-freedom hand controller. In the EVA tools area, the helmet-mounted head-up display will be evaluated, and a generic restraint system for use on unprepared surfaces will be developed. The space station control room simulator will be used to study the applicability of advanced input/output devices. Space station habitat design alternatives will be evaluated in a habitat module mockup that is now under construction. Validation will begin on the man/machine function allocation algorithm now under development.

*Space data and communications research and technology*

The space data and communications programs consists of research and technology efforts to advance the capability in processing, storage, management, and communication of space-derived data.

The objectives of the data systems program are to provide the technology to enable more cost-effective space-derived information, to increase substantially the capability of onboard and ground processing, and to provide the computational systems necessary for the modeling of global phenomena. In 1983, the massively parallel processor (MPP) was delivered to Goddard Space Flight Center. This unit contains 16,384 processors; is capable of executing six billion instructions per second; and, provides a major technological advance in computational capability for multidimensional modeling. Early exploratory applications include image analysis and weather and climate modeling. In addition, an experimental 250 million bits per second optical-fiber data bus was demonstrated in FY 1983 at Langley Research Center. This technology, required for future spacecraft, is potentially expandable to ten billion bits per second through the use of wave division multiplexing. An optical disk recorder will be completed and delivered to Marshall Space Flight Center in 1984. The delivery and integration of this unit will provide an online storage capacity of 10 trillion bits. This system will ingest data at a rate of up to 50 million bits per second and will automatically catalog and archive data packets to support online

users. A major effort has been initated to apply the DOD Very High-Speed Integrated Circuit (VHSIC) technology to spacecraft onboard processors. A tenfold increase in performance is anticipated from this effort.

The objective of the communications technology program is to provide the high risk research and technology required to ensure U.S. preeminence in satellite communications. In 1983, a research program in intersatellite optical communications was initiated. The first 29 gigahertz (GHz) tunnel ladder traveling wave tube (TWT) was fabricated, and its proformance exceeded specifications. The dynamic velocity taper was demonstrated experimentally on two TWT tubes resulting in a 25 percent improvement in output power and more than 100 percent improvement in the linear amplification range. The dynamic volocity taper has already been included on production TWT's and will be tested further in the future. The multistage depressed collector (MDC) has been applied to a high performance TWT that is a candidate for use in an Air Force electronic countermeasure program, increasing tube efficiency by 50 percent. In the future, the application for low secondary electron yield materials to the MDC will be pursued. A four-stage, 20 GHz monolithic microwave integrated circuit (MMIC) amplifier has been developed as one of the components of the MMIC transmitter module. This MMIC amplifier exceeded specifications for power and efficiency. The near-field antenna test facility was brought into operation in FY 1983 and will be used to test proof-of-concept antenna concepts. A 30 GHz low-noise receiver was developed and a 12-watt solid state X-band amplifier, for use as a component for a deep space transponder, has been developed jointly by the Office of Aeronautics and Space Technology (OAST), the Office of Space Science and Applications (OSSA), and the Office of Space Tracking and Data Systems (OSTDS). Computer simulations of surface distortion of large, deployable parabolic reflectors have been verified experimentally in FY 1983 and tests of the 15-meter diameter antenna will begin in FY 1984.

The development of a high-performance onboard array processor for space platform data processing will be initiated. This will enable analysis and experiment control critical to instrument management and onboard manufacturing. The computational requirements for global habitability modeling and analysis demand an increase of three to four orders of magnitude in performance.

In FY 1985 efforts will continue to advance TWT technology by continued work on the dynamic velocity taper, the tunnel ladder and multistage depressed collectors made from low secondary yield materials. Research on the critical components for a laser intersatellite link will be continued. Work on TWT's, impact avalanche transit time (IMPATT) diodes, and low-noise receivers for 60 GHz intersatellite links will also continue. Efforts to develop MMICs for use as transmitters at 20 GHz and low-noise receivers at 30 GHz, and work on novel antennas and antenna with multibeam feeds will be completed and evaluated. The X-band transponder for deep space communications will be demonstrated. Activities in space communications, such as multiuse, multifrequency antennas, antenna coverage modeling, wide bandwidth intra-vehicle and prox-

imity communications, and laser ranging and tracking, will be continued.

*Chemical propulsion research and technology*

The objective of the chemical propulsion program is to provide the technology base for improving the life, performance, reliability, and maintainability of chemical propulsion system for future space transportation and spacecraft system. The program includes efforts directed at longer life, reusable propulsion systems for lower cost opeations; high-performance, variable-thrust propulsion for increased mission flexibility and capability; and efficient, long-life, on-board auxiliary propulsion for precise attitude control and station-keeping functions.

Technology for large thrust (SSME class) advanced, high-pressure, reusable propulsion system is focused primarily on technology to extend the life of engine components subjected to the severe internal dynamic environments, both mechanical and thermal, that are typical of high-pressure rocket engines of this class. Although both hydrogen-fueled and hydrocarbon-fueled engines will benefit from these technology advances, primary emphasis is on the former. Advanced thermal barrier coating processes have been developed that show promise of greatly increasing the life of highly stressed turbine blades. Silicon chip technology and micro-electronics applied to advanced pressure transducer designs have demonstrated much greater accuracy, reliability and reduced temperature sensitivity in breadboard system testing. Fabrication of hybrid bearings for both liquid-oxygen and liquid-hydrogen high-pressure pump service has been completed, and testing of the bearing tester has been initiated.

Work on advanced, high-performance, variable-thrust, orbital transfer propulsion is now focused exclusively on exploratory technology development with the objective of verifying the feasibilty of each of the promising conceptual designs that had been generated previously. The concept of using oxygen as a regenerative coolant and as a turbine working fluid demands the use of materials that are compatible with oxygen under a variety of operating conditions, both normal and abnormal, including accidental rubbing of parts. A program to evaluate potentially compatible materials under rubbing and particle impact conditions has been initiated. Analyses of components promising highly efficient operation over a wide throttling range have been completed and fabrication of parts being readied for rig testing has been initiated. These include partial admission turbines, pump high-diffusion crossovers, and heat transfer enhancing combustor designs.

In the auxiliary propulsion area, trade studies identifying critical technologies for candidate oxygen-hydrogen drag make-up and attitude control systems have been completed, and technology efforts initiated. Small gaseous oxygen-gaseous hydrogen thruster testing has demonstrated the feasibility of attaining desired performance without sacrificing thruster life. System definition studies have been initiated to establish optimum component operating conditions.

The technology effort for advanced, high-pressure, reusable propulsion systems will be directed toward continued development of

analytical models designed to define hot gas flow distributions and resulting dynamic loads; the characterization of the structural response and material behavior of parts subjected to these dynamic loads; and the development of accurate life prediction techniques. In addition, advanced designs with greater load resistance will be developed, and advanced instrumentation will continue to be developed to more accurately measure the true engine dynamic environment and to provide better validation of computer codes analytically simulating the engine environment.

The focus of research effort in hydrocarbon-fueled, high-performance, reusable propulsion systems will continue to be on fundamental work in combustion, stability, heat transfer, and cooling. Experimental testing with subscale hardware will be conducted for the purpose of validating computer codes that analytically model combustion processes, carbon deposition, and heat transfer coefficients. Cold-flow rig testing will be used to supplement hot firings with subscale hardware.

Technology for variable-thrust orbital transfer will emphasize component research activities that are directed toward generating analyses and design criteria for major engine components that are critical to achieving the life, performance and maintainability goals essential to a space-based, man-rated orbital transfer vehicle which uses aeroassist recovery at low-Earth orbit. Critical components include high-performance, long-life, high-heat transfer combustors, highly efficient variable flowrate turbopumps, and integrated diagnostic instrumentation. Test rigs will be used to validate analytical models and advanced component designs as they evolve.

Auxiliary propulsion technology will focus on component technology development guided by the system definition and evolution studies that have now been completed. Primary emphasis will be on gaseous oxygen-gaseous hydrogen thruster performance and life evaluations, propellant conditioning components and diagnostic instrumentation.

*Spacecraft systems research and technology*

The objective of this program is to develop and demonstrate technology for the advanced Earth-orbiting and planetary spacecraft necessary to satisfy planned space missions. Research and technology activities are conducted in those areas where a systems approach is essential to bring individual discipline accomplishments into integrated technology capabilities. The goal is the effective transfer and use of technology in future spacecraf within acceptable levels fo risk and cost.

The advanced Earth-orbiting spacecraft technology program includes Earth observation, scientific, and communications spacecraft. Efforts include defining the technology requirements, developing systems concepts, developing advanced analytical tools to aid in spacecraft design, and defining the flight experimental programs to validate broadly applicable technologies that will enable future planned missions.

The final assembly of ground test hardware for a 55-meter wrap-rib aperture, 4-rib, 3-gore mesh antenna will validate deployment and retraction and also mesh roughness performance. Hardware for a hoop/column antenna model is also being assembled and

readied to undergo radio frequency testing in a near-field antenna test facility. Further structures and structural/dynamics testing is planned. Flight experiments to validate antenna systems technology, which build on ground test experience, are in a preliminary definition age. An interactive conceptual design and analysis tool is under development to enable early technology assessments and tradeoffs to guide spacecraft discipline and flight experiment definition. System analyses are underway to define advanced configurations and technology requirements for precision pointing spacecraft, intersatellite optical communications, and communication satellite bus technology. In addition, the definition and assessment of configurations and technology requirement options for a 10- to 30-M large infrared/submillimeter reflector telescope are in progress. This joint effort with the scientific community will provide various sets of scientific requirements as inputs for the system technology tradeoff studies. The laser reflector remote displacement measurement system and shuttle bay video measurement systems are being completed for a large space systems structural dynamics experiment using the 4Mx10M solar electric propulsion stage (SEPS) array.

The effort to identify the high-leverage technologies for future commercial and military spacecraft will be expanded. The work will center on advanced spacecraft bus technologies and integrated subsystem technologies. In addition, evaluation of in-space experimental testing requirements for large space antenna systems technology will continue with analyses of the integrated structures, controls, and electromagnetic systems technologies needed for shuttle/station attached antennas. Emphasis will be placed on defining technology experiments that have a high generic value and aid the understanding of the control of large space systems. Development of analytical tools will include integration of dynamics and controls modules into the advanced spacecraft conceptual design tool.

*Transportation systems research and technology*

The objectives of this program are to: identify the technology requirements for advanced transportation vehicles which satisfy anticipated national needs and integrate these requirements into a comprehensive plan for supporting a technology base; develop technology programs which satisfy these requirements; and support the development, enhancement, and improvement of the space transportation system in areas of recognized technical expertise. These objectives are accomplished through system level studies, analyses, and requirements definition efforts, as well as system and discipline research and technology efforts utilizing ground-based facilities, in-space hardware, and instrumentation which permits the shuttle orbiter to be used as an advanced research vehicle.

Flight data from both the orbiter development flight instrumentation (DFI) and the orbiter experiments (OEX) have been used to verify preflight predictions of the shuttle's aerodynamic performance. Prediction methods have been refined and updated with flight data from DFI and OEX. These predictions have been used to certify the orbiter's thermal protection system, to support the expansion of the vehicle's operational envelope, and to support the

completion of the space transportation system (STS) operational flight test (OFT) program.

Instrumentation developed by the OEX program for determination of the aerodynamic coefficients of the orbiter was flown successfully on all shuttle flights diring FY 1983. Aerodynamic coefficient instrumentation was also installed on the second orbiter, Challenger, and has supported certification of Challenger. OEX instrumentation to measure tile-gap heating and thermal protection system surface catalytic heating properties was flown during FY 1983. Information from the tile-gap experiment was used to investigate anomalies experienced on early shuttle flights associated with scorching of the gap-filler material. Sensors which measure payload environment in the cargo bay were flown during 1983. Data collected are being used to validate structural and acoustic load models to predict payload-bay environments. These models will provide design specifications and test environments for satellites and payloads flown in the future.

An effort to identify systems level requirements for the use of aeroassist to recover reusable orbital transfer vehicles was continued and two major studies of vehicle concepts in the low-to-moderate lift/drag regime were initiated and completed in FY 1983. These studies identified the enhancing and enabling technology for aeroassist and showed that thermal protection was the driving technology. A study of a representative post-2000 vehicle was completed. the results identified key technology issues related to the vehicle conceptual design, especially the structural and thermal protection systems associated with the integral and nonintegral tankage vehicles. The results also identified major increases in ground and flight operation flexibility related to a decoupled cargo bay. Orbit-on-demand studies were initiated for conceptual design of a quick response Earth-to-orbit vehicle.

Systems analyses efforts will continue for definition of scope and direction of technical programs needed to reduce the cost and improve the performance of future space transportation vehicles. Specific technology issues from previous future space transportation systems (FSTS) and orbit-on-demand (OOD) studies will be addressed. In addition, heavy-lift cargo vehicles (HLCV) system and subsystem trade studies will be made to identify an optimal HLCV concept for NASA/DOD requirements. The studies will focus on technology to enable low cost delivery of both solid and liquid cargoes to low Earth orbit. The study to identify the technology data base and systems level requirements for the use of aeroassist to recover orbital transfer vehicles will continue; specific aerobraking technology issues and the requirements for space basing will be emphasized. System studies for a potential high lift/drag (L/D) entry research vehicle will be initiated, including an evaluation of the use of the Shuttle to deliver the research vehicle to orbit.

A major OEX activity during FY 1985 will be the installation of key aerodynamic/aerothermodynamic research experiments on the Columbia. These include low- and high-altitude research-quility air data systems and an infrared scanner in the vertical stabilizer to measure entry heating on the shuttle upper wing and fuselage surfaces. The first flight for these experiments is expected to be in FY 1985.

The shuttle flights in FY 1985 will continue to be used as a source of flight data for the validation of analytical and ground facility test techniques. The resulting research-quality data base of critical vehicle characteristics will permit advanced vehicle concepts and designs to be analyzed with increased confidence and, thus, designed with reduced technical risk and better cost control.

Two flight control experiments will be integrated into the orbiter in FY 1985. The first experiment will quantify orbiter handling qualities; the second will provide flight data on an advanced, adaptive autopilot. This data will permit the supporting technology programs to be responsive to actual flight conditions.

Several advanced thermal protection system test panels will be in development for flight opportunities in FY 1985/1986. These panels will provide actual flight data on more durable, higher performance concepts which could become options for retrofit on the current orbiter fleet, as well as candidate for subsequent orbiters. The panels will provide a validated data base for the thermal protection system for advanced post-shuttle vehicles.

*Platform systems research and technology*

The objective of this program is to develop the systems level research and technology capability which enables future manned large space platforms. These research and technology activities require a multidisciplinary approach to determine technology requirements for interacting systems, for phased mission needs, and for ground and in-space tests of systems technology. The generic system and integrative technology efforts support the system and subsystem developments necessary for future space platforms and space stations to satisfy science, technology, applications, and operational mission requirements. Efforts in the areas of system analysis, operations technology, and crew and life support technology are directed toward reducing the cost of station operations and increasing station productivity and versatility.

Functional requirements definition of automated unmanned spacecraft have been completed, and the techniques are being adapted for determining system level technology requirements of an inhabited, highly automated platform. Data systems architectural studies have begun to determine technology requirements for highly automated, evolvable data systems both for platform operation and user experimentation. The system strategies and technology requirements for highly automated systems, such as a multihundred kilowatt power subsystem, are being defined. Experimental validation of software is underway for simulation and analysis of a teleoperated satellite servicing system. Simulation and analysis of soft docking and berthing are identifying technology guidelines for latches, attenuators, and microprocessor controls; engineering design of soft docking systems for technology testing has begun. Studies of large structural subsystem interactions are being conducted using interactive graphic analysis and system simulation tools. Advanced life support systems technology capable of partial closure on-board of the water, air, and waste cycle is being verified; a portable life support system and on-orbit servicing system are being defined that would provide spacebased extravehicular activity (EVA) systems. Platform systems analysis have resulted in fo-

cusing on critical technologies for manned platforms to enhance the cost-effective operation and evolutionary growth in size and capability. Emphasis is on advanced automation techniques, human factors research for station productivity and EVA, auxiliary propulsion for orbital attitude control and station-keeping, fuel handling, distributed and adaptive control, and energy management.

For FY 1985, the platform systems research and technology program is grouped into three subprograms: system analysis, operations technology, and crew and life support technology.

The system analysis efforts will complete evaluation of automated and autonomous system concepts which could provide an early capability, and analytical and experimental verification of space assembly and construction concepts. Based on system level analyses, requirements for platform autonomy, information system architecture, human-machine partitioning, and automation technology will be determined.

Operations technology includes experimental investigations of teleoperations and robotics through software simulation and hardware validation. A hardware/software simulation of remote orbiting systems for the teleoperated servicing of satellites and structural assembly will be conducted. Systems integration of existing teleoperation component technology will be analyzed and simulated to identify technology needs for EVA-equivalent telepresence capability.

Crew and life support research and technology activities will continue in water reclamation, air revitalization, and waste disposal. The technology to enable closing of the water and air loops will be treated in an incremental fashion. Design of an advanced technology space-based EVA portable life support system and its on-board servcing system will be completed, and fabrication started.

SYSTEMS TECHNOLOGY PROGRAMS

FISCAL YEAR 1985 FUNDING LEVELS

| | |
|---|---|
| Space flight systems technology | $7,000,000 |
| Chemical propulsion systems technology | 2,100,000 |
| Total | 9,100,000 |

*Space flight systems technology*

The objective of the space flight systems technology program is to conduct research in space, capitalizing on the use of the Space Shuttle, Spacelab, and free-flying vehicles, where it is impossible or too costly to simulate the space environment in ground laboratories. The space environment uniquely provides long-term, zero gravity and the combination of space-vacuum and space-radiation environments necessary to the development and characterization of many technologies important to future space systems. This program element encompasses the design, development, integration, and flight test of experiments and the development of special purpose, reusable, flight research facilities for use in space.

Current experiment efforts include: (1) a series of structures experiments to understand the static, dynamic, and control characteristics of structural elements leading to the capability to produce the next generation of precision deployable/erectable large space

systems; (2) a cryogenic fluid management experiment which will provide the understanding for storage, acquisition, and transfer of cryogenic fluids; and (3) thermal and space plasma interaction experiments that will provide the technology data base for future multi-100kw power systems.

In FY 1984 the following experiments will have completed preliminary design review: Mast structure (MAST), cryogenic fluid management facility (CFMF), voltage operating limit test 1 (VOLT 1), and thermal energy management process 1 (TEMP 1). In addition, launch of the following experiments will occur in 1984: long duration exposure facility (LDEF), drop dynamics facility, feature identification and location experiment (FILE), solar cell calibration facility, and the solar array flight experiment (SAFE).

In 1985, the superfluid helium experiment will go to flight; the long duration exposure facility, having orbited for approximately twelve months, will be retrieved by the shuttle and the experimental data analyzed. The ion auxiliary propulsion system will have completed technology readiness and will be awaiting flight on a DOD spacecraft.

Long lead time hardware procurements and component fabrication for the CFMF, TEMP 1 and the MAST experiments will be initiated. Hardware fabrication and systems testing will be completed for the VOLT 1 experiment in preparation for a 1986 flight date. Additional flight experiments and concept definition activities will be initiated based on evolving requirements identified in the research and technology base program, technology urgency, and funding availability.

*Chemical propulsion systems technology*

The objective of the advanced SSME systems technology program is to utilize a testbed engine assembled from existing SSME hardware for the purpose of providing data to assist in developing models and validating analytical methods and advanced component concepts emanating from the SSME base research and technology program. Initially, advanced instrumentation will be installed on the engine in order to experimentally establish the internal dynamic environments of the engine. This data base will then be used to validate computer codes developed to analytically simulate these dynamic environments, which will have been validated initially through the use of test rigs designed to experimentally simulate the engine environments to the degree possible. In addition, advanced components designed for extended life and/or performance will now be evaluated at the engine system level in the true engine environment. This will be accomplished through the assembly of engine components, such as turbopumps or combustors, with advanced technology subcomponents (e.g., bearings, seals, turbine blade dampers/coatings, advanced materials, etc.) installed and then delivered to the testbed engine for engine level testing. The subcomponent technology advances will have been screened and evaluated initially in test rigs, again simulating the engine environments.

The testbed engine will provide the lowest risk path for transferring technology from the research and technology base program into a mainstream development program such as the SSME. Many

promising technology products are beginning to emerge from the research and technology base program that could find early application in the SSME and which will be ready for testbed engine testing in the FY 1987–1988 time frame. In addition, the testbed engine program will provide the experimental tool needed to evaluate longer term, higher risk technology items that will lay the foundation for more advanced SSME derivatives or for even more advanced high-pressure, reusable engines of the future.

The SSME system technology program funding will allow the acquisition and assembly of a major engine component that will have advanced technology subcomponents incorporated into it and which will be ready for testbed testing in the FY 1987–1988 time frame. The initial component will be a turbopump, incorporating advanced technologies such as longer life bearings, low-leak seals, and improved turbine blade coatings. In addition, advanced instrumentation will be fabricated and delivered to the testbed engine for environmental mapping of engine dynamics in FY 1987. Primary focus of the early advanced instrumentation program is on high-response pressure and temperature sensors.

## Standards and Practices

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Standards and practices | $4,900,000 |

The objective of the standards and practices program is to support Agency goals through activities in systems engineering; reliability and quality assurance; safety; software assurance; and program practices which reduce program risks, improve product confidence, and encourage good program procedures in the technical execution of NASA programs.

During FY 1982, the Office of the Chief Engineer was reorganized to consolidate agency-level safety, reliability and quality assurance activities, and to assume four new areas of responsibility (aerospace flight systems; data and communication systems engineering; test and environmental systems; and engineering technology). This expansion of the oversight function in the engineering discipline area has the objectives of improving product quality, increasing confidence in NASA's ability to achieve mission objectives and accelerating the pace of achieving greater productivity. In FY 1982 through FY 1983, reliability and quality assurance activities have emphasized solving concerns related to degradation of critical electronic parts in space applications; laying a solid foundation for testing and qualifying very large scale integrated (VLSI) circuits for future use in the space program; assessing and mitigating the effects of space radiation on electronics in space; developing nondestructive test techniques for verifying product quality; evaluating NASA-wide software practices with goals to improve productivity and reduce costs; and continuing materials and parts assurance activity. Program practices activities include continuing support to voluntary consensus efforts which will result in a new American Institute of Aeronautics and Astronautics (AIAA) standard for symbols and units for use in planning and design of large space structures; workmanship standards; support to the measurement of the Shuttle payload bay dynamic, acoustical and thermal environment;

and providing electrostatic discharge information designed to achieve good practices which will minimize the potential loss of electronic systems containing microcircuit parts. In the area of safety, activities include assessing the ignitability of metals in oxygen; studies concerning safe siting of future pressure vessels; development of an accident investigation training program; and a project to assess the use of an in-flight aircraft data recorder to enhance maintenance procedures.

In support of the goals of the Agency, the FY 1985 standards and practices program will continue to conduct activities related to reliability and quality assurance, safety, software assurance, and program practices. Emphasis includes software engineering assurance, special technology reviews and risk assessments; improved assessment and evaluation of test facility capabilities, hardware and, particularly, software systems engineering assessments; and continuing special activities to maintain or improve productivity, quality and mission success. Non-destructive testing and evaluation techniques and standards will be extended to new materials, such as composites, and to developing pressure vessel hazard mitigation guidelines. The FY 1985 funds will also continue to provide for special Congressional or NASA directed taskings which result from technical problems arising from programmatic activities.

**10. TRACKING AND DATA ADVANCED SYSTEMS, $15,300,000**

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Advanced Systems | $15,300,000 |

The overall objective of the advanced systems program is to perform studies and provide for the development of tracking and data systems and techniques required to: (1) obtain new and improved tracking and data capabilities that will meet the needs of approved new missions and near term new starts; and (2) improve the cost effectiveness and reliability needed for overall support of the total mix of spaceflight missions.

This program is a relatively small but vital portion of the Space Tracking and Data Systems Program. Activity continues under this program to assess and make use of the dramatic changes taking place in the state of the art in telecommunications and computer technology. Such effort is critical for proper planning and for the application of new technology to future support capabilities that are cost effective and reliable. Efforts include the investigation of upcoming missions and studies of ground systems and telecommunications links to determine design approaches and overall tradeoffs for the lowest life cycle costs to support future space missions.

The following are examples of activities planned for FY 1985. Techniques aimed at obtaining tracking accuracies to the sub-decimeter level for Earth-orbiting spacecraft will be investigated. Such precision is needed to gather image and topographic data for science and applications programs. The techniques to be investigated include using the military's Global Positioning System and Very Long Baseline Interferrometry. Work will also continue on extremely precise radiometric techniques for determining angular direction of future planetary missions to an accurary of five nano-radians. Such activity typically leads to improved spacecraft naviga-

tion and the carrying out of science experiments not previously possible.

New methods of increasing NASA's capability to communicate with spacecraft will also be investigated. Improving space-to-ground link performance can benefit many future missions by reducing mission costs or increasing the amount or quality of the data returned. Studies and developments will include investigations of antenna surface tolerances and pointing control techniques precise enough to operate at K-band. Future deep space missions using K-band rather than X-band will achieve a several-fold improvement in telecommunications. In addition to K-band, the program includes the investigation of millimeter wave technology and optics to meet telecommunications needs beyond the 1980's.

As the TDRSS era begins with the launch of the first of three satellites, the data handled from Earth orbital missions has increased from a peak of 15 megabits per second to 85 and is expected to reach the TDRSS design limit of 300 in the future. These future requirements result from high resolution sensors such as multispectral scanners and synthetic aperture radars plus a continued growth in single access users of the TDRSS. New techniques and systems will be developed for ground transfer and processing of high volume data. These include custom Very Large Scale Integrated (VLSI) curcuitry design, digital receivers, filters, and high data volume processors, decoding schemes, and optical disc storage to handle the increasing image data buffering requirements.

To keep systems life cycle costs at a minimum in an era of expanding use of digital systems, efforts will be increased on software development technology that will aid in automated systems design, integration, test and maintenance. Methods and techniques will continue to be investigated to reduce future manpower levels needed to operate the mission control and tracking facilities, and to provide the necessary real time interaction between the experimenters or investigators and their space experiments.

## SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

### SUMMARY

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| 1. Shuttle production and operational capability | $1,490,600,000 | 159 |
| 2. Space transportation operations | 1,329,000,000 | 167 |
| 3. Space and ground network, communications and data systems | 780,700,000 | 172 |
| Total | 3,600,300,000 | |

#### 1. SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY, $1,490,600,000

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Orbiter | $656,800,000 |
| Launch and mission support | 219,800,000 |
| Propulsion systems | 599,000,000 |
| Changes and system upgrading | 15,000,000 |
| Total | 1,490,600,000 |

The objectives of this program are to provide for: the completion of the national fleet of Shuttle orbiters; the production and capability development of the propulsion systems; the mission preparation, mission control, and launch site capabilities; and, the potential changes and upgrading of the Space Transportation System.

The planned four-orbiter fleet includes: Columbia (OV-102), the orbiter vehicle developed under the Space Shuttle design, development, test and evaluation (DDT&E) program and used for the first five flights and the first Spacelab flight; Challenger (OV-099), the second flight orbiter, which was fabricated using elements of the DDT&E structural test article; and, two orbiters—Discovery (OV-103) and Atlantis (OV-104) of a lighter-weight configuration. OV-103 is being processed at KSC for its first flight in FY 1984. The planned delivery date for OV-104 is December 1984. OV-102 underwent modifications at KSC in order to support the launch of the first Spacelab mission in November 1983. The final phase of modifications for OV-102 is now planned for FY 1985. Work was initiated in FY 1982 on modifications to orbiters and the related systems integration analyses for the use of the Centaur and its payloads. The provisioning of orbiter spares is an on-going activity to support the requirements for the initial lay-in of line replaceable units of

equipment at the launch site. In addition, the budget provides for the extensive acquisition of orbiter structural spares to support the four-orbiter fleet.

Launch and mission support provides for the second set of processing stations at KSC to support parallel orbiter processing; the additional astronaut training, mission preparation and mission operation capabilities required for higher flight rates; the modifications to the launch site capabilities to accommodate the new Centaur upper stage; and, studies and analyses of program level improvements for the operations and management of the STS. The first line of KSC facilities (funded under Space Shuttle DDT&E) supports the launch processing and checkout of one orbiter vehicle at a time from landing through launch. The second line of processing stations allows for parallel processing of orbiters to meet the East Coast launch rate of up to twenty flights per year. A third Shuttle training aircraft is being modified to support increased training requirements and to permit the existing two aircraft to be overhauled when fatigue considerations make this necessary. The upgrading of the Mission Control center (MCC) will provide for reconfiguration of the JSC MCC to support two, and finally three, simultaneous orbiter operations (flights, tests, or simulations). Support for the Vandenberg launch site, including provision of three abort landing facilities, is proceeding. Inflight refueling capability for the Shuttle Carrier Aircraft (SCA) will be available prior to initiation of Vandenberg launches.

Propulsion systems provide for the production of the SSME and the development of the capability to support operational requirements estabished for the SSME, SRB, and ET. The SSME program includes: production of the main engines necessary to outfit and provide spares for the orbiter fleet, ground testing in support of engine development, and an anomaly resolution capability. The SRB production and capability development activities include: the development of the solid rocket motor's FWC the redesign of hardware to meet reusability and cost savings requirements, and the procurement of tooling and equipment to support a flight rate of 24 flights per year. In the ET program, the objectives are to provide manufacturing tooling and equipment to support the 24 per year flight rate and to improve manufacturing techniques and management processes in order to reduce the time and cost of producing tanks. Systems engineering support and main engine testing in the main propulsion test article configration are both provided in system support.

Changes and systems upgrading provides funding for potential changes and system modifications as well as unanticipated new requirements not covered in the budget estimates for the above activities and other program elements.

## ORBITER

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Orbiter production | $276,600,000 |
| Systems integration | 48,700,000 |
| Orbiter spares | 331,500,000 |
| Total | 656,800,000 |

Successful continuation of the orbiter production activities remains the objective of this program. This production program will provide the authorized four orbiter fleet plus a group of selected major structural spare elements for that fleet.

With the delivery of OV-103 (Discovery) in November 1983, the number of orbiters available for flight has increased to three: OV-102 (Columbia) from the DDT&E phase and OV-103 (Discovery) and OV-009 (Challenger) from the production phase.

During the past year, Columbia underwent modifications at KSC. These modifications were necessary to conduct the recently completed Spacelab mission. OV-102 will undergo a final period of modifications in 1985 to bring it to its fully operational configuration.

Discovery was delivered in early November 1983, approximately five weeks behind the originally planned date of September 30, 1983. This delay was made in order to complete addition work on the vehicle and to avoid having OV-103 arrive at KSC while both Orbiter Processing Facility (OPF) bays were filled. This latter circumstance arose when OV-102 was rolled back to the OPF while changes to the SRB were made prior to STS-9.

Substantial progress was also made on OV-104. Several structural elements have been delivered to Palmdale including the mid-fuselage, wings, vertical tail, and payload bay doors. Mating of these elements is underway and thermal protection system installation has been initiated. Additional modules and systems will be delivered over the next several months and the vehicle will be in final assembly and system installation phase during FY 1984.

The structural spares program was initiated in FY 1983 in order to maintain a continued production capability and to assure adequate structural repair capability in the event of damage to one of the four orbiters. Fabrication of these major elements is underway and will continue throughout the year. Structural assemblies include the wings, aft thrust structure engine compartment, crew module (including the nose and cockpit), mid and aft fuselage sections, payload bay doors, vertical tail, and the orbital maneuvering system pods.

The procurement and fabrication of orbiter spares is ongoing. A concerted effort was made to better define the spares requirements and production capability at various vendors. Provisioning conferences were held at 36 of the major subcontractors in support of this effort. Studies were conducted of suppliers who were completing orbiter commitments to determine current and future production and repair capabilities. Where necessary, contracts were let to insure production and/or repair capability.

A major effort in FY 1985 will be the completion of the final stages of manufacturing on OV-104 at the Rockwell Palmdale fa-

cility, including final assembly and integrated testing, leading to its delivery in December 1984. Another major effort in FY 1985 is the full-up modification of OV-102 to its operational configuration (at Palmdale) including changes for vehicle load requirements. FY 1985 funding provides continuing procurement of major structural components as spares for the orbiter fleet. These structural components will include elements such as wings, vertical stabilizer, crew module, payload bay doors, and aft thrust structure. These items will be assembled into varying stages of completion so that they can be used as structural spares for the current fleet. FY 1985 funding will also be utilized for performance augmentation activities primarily to conduct orbiter load analyses in support of the FWC development program, and for modification of OV-099 and OV-104 to accept, boost, and deploy the wide-bodied Centaur upper stage. Ground support equipment and test hardward are also being provided to support KSC activities. In FY 1985, systems integration activities will be concentrated on the engineering analysis and integration support for vehicle capability changes including the Space Shuttle performance improvements (such as the FWC); analysis of compliance to system specifications as the result of performance improvements, including the investigation/resolution of flight problems; and support of the Vandenberg launch site activation.

Logistics support to the Space Shuttle program requires the lay-in of orbiter initial spares and rate spares to meet the 24 per year flight rate and for support to ground processing operations as the fleet size and flight rate increase. Projected failure rates for each item and turnaround times for repairs are two significant factors in determining the quantity of spares to be procured. The funding for orbiter spares covers not only the cost of orbiter flight spares and ground support equipment spares, but also the logistics support to analyze requirements and procure these spares. In addition, acquisition of maintenance test equipment will be initiated to support establishment of depot maintenance capabilities.

### Launch and Mission Support

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Launch site equipment | $86,800,000 |
| Mission support capability | 98,000,000 |
| Mission operations capability | 50,000,000 |
| *General reduction* | *−15,000,000* |
| Total | 219,800,000 |

The first line of facilities previously activated at KSC supports the launch processing and checkout of an orbiter vehicle form landing through launch. The second line of processing stations is being phased in to support parallel launch processing of more than one orbiter through the various work areas. The second high bay of the OPF and the second MLP were activated in late FY 1982 to support parallel processing of OV-102 and OV-099. The second set of high bays in the VAB, the software production facility, and the second control room were activated in FY 1983 to enable parallel processing through orbiter—ET mate. When Pad B is activated in FY 1986, parallel processing will be possible from the start of OPF flow through launch.

A solid rocket booster processing and storage facility will be activated in FY 1984 to provide off-loading of segments from rail cars, segment rotation capability, storage capability for two flight sets (sixteen segments) at KSC and the buildup of SRB aft segments. A third MLP will be activated in late FY 1986 to help meet the flight rate scheduled in 1987 and beyond. Facility modifications supporting the FY 1986 Centaur launches are in process. A new responsibility is to maintain the on-site railroad which was formerly maintained by the Florida East Coast Railroad. A Federal court decision in FY 1983 transferred ownership of the entire railroad to KSC along with the responsibility of restoration and maintenance.

Also under launch and mission support are the capability investments in the JSC program support areas necessary to support a 24 flight per year capability. These include additional simulation capabilities, necessary replacements of obsolete equipment, and the production costs of procuring the Government furnished equipment. This equipment includes the extravehicular mobility units (space suits) as well as other crew related equipment. Development of needed changes to the spacesuit (soft goods and portable life support system) to meet zero pre-breathe mission requirements and facilitate extravehicular activity operations are being undertaken. Modification of a Gulfstream II for use as a third Shuttle training aircraft (STA), and the provision of inflight refueling capability in the Shuttle carrier aircraft (SCA) is included here. Both efforts will be completed in FY 1985. Specific capability development items include TACAN navigation equipment, data reduction and flight design system improvements.

The Mission Control Center upgrading (Level II) is also within launch and mission support. The Mission Control Center (MCC) upgrading (Level II) will provide for the reconfiguration of the MCC at JSC to support the STS's operational flight schedule requirements. The use of additional hardware, equipment, and software to operate the MCC will provide for systems monitoring and flight control capability in support of two and later three (24 flights per year capability) simultaneous operations (flight, test or simulation). Completion of the second flight control room on the second floor of the MCC and capability for two vehicle operations is planned for April 1984.

Outfitting and activation of launch pad B, MLP-3, and the Centaur-related modifications to KSC facilities and underway now and will continue to be the major activity during FY 1985. Pad B operational readiness date (ORD) of January 1, 1986, MPL-3 ORD of September 1986, and two Centaur launches in May 1986 continue on schedule. Restoration of the KSC railroad will continue.

In the area of mission support capability, the expansion of communication and data handling will continue in FY 1985. Development of an advanced extravehicular mobility unit will be initiated. Production of Government furnished equipment including extravehicular mobility units, cameras, and other crew equipment is continuing in order to achieve the inventory required to support the 24 per year flight rate.

The mission operations capability area will support completion of the modification of a third Gulfstream II for use as an STA; continued mission support activities for training and simulations; contin-

ued reconfiguration of the MCC II to support operational flight requirements leading to three-vehicle capability; make the Vandenburg Air Force Base interface operational; continue development of three western abort sites; and begin early software development and hardware acquisition for Shuttle Post-Flight Data Reduction Facility.

### Propulsion Systems

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Main engine | $432,600,000 |
| Solid rocket booster | 103,700,000 |
| External tank | 61,600,000 |
| Systems support | 1,100,000 |
| Total | 599,000,000 |

Propulsion systems provide for the production of the SSME's and the development of the capability to support operational requirements established for the SSME, SRB, and ET. The SSME program includes the production of the main engines required for the orbiter fleet, the procurement of spares, ground testing operations, and anomaly resolution capability. In the SRB, the development of the FWC solid rocket motor and the redesign of the hardware to meet program requirements for reusability and operational cost reduction are being pursued. In the ET program, the objectives are to provide manufacturing tooling and equipment in addition to improved manufacturing techniques and management processes to reduce the time and cost of producing tanks. Also included within SRB and ET requirements is the procurement of manufacturing tooling and equipment to support fabrication and transportation for meeting the 24 per year flight rate. Systems support primarily provides for the testing of the SSME in the main propulsion test article configuration in addition to providing systems integration engineering support.

The main engines continued their record of superb flight performance with the five flights of the Space Shuttle completed last year. These flights were completed with no SSME anomalies that impacted flight performance. However, a series of engine problems was experienced during FY 1983 which required significant, unplanned maintenance. On one of these occasions, the lack of logistics spares resulted in the delay of the STS–6 flight. Also during 1983, the initial certification testing at the 109% full power level (FPL) was completed. The SSME can now be used for those missions requiring the higher thrust level. The total SSME ground test experience now exceeds 1,000 tests totaling approximately 200,000 seconds of test time. This experience includes 400 tests exceeding 40,000 seconds of operation at the FPL.

During the course of FPL testing, it became apparent that design margins are inadequate for full power level flight operation and that the current SSME configuration requires an unnacceptable amount of maintenance at that power level. Consequently, the SSME program has been re-planned so as to reduce the maintenance required and to provide quantities of logistics hardware adequate to preclude the flight delays experienced with STS–6.

Design modifications are underway to improve component life, increase reliability, and reduce the high maintenance costs. The solution to the environmental problems appears to require not only the modification of the turbopumps but also the reduction of operating temperatures and pressures induced by the design of the key elements of the powerhead. Due to the design and testing lead times, changes will be introduced incrementally. The first of these changes will occur in the 1985/1986 time span when the current engine will be retrofitted with improved turbopumps. The second change will be to redesign the hot gas manifold and the powerhead to change the operating environments experienced by the pumps. Efforts are being made to introduce competition into this phase of the improvement program to assure that the Agency takes maximum advantage of all available talent. Prior to implementation into flight engines, these changes will be put through an initial certification test. They will also be incorporated into the flight certification extension program to demonstrate long term usage.

The number of engines being procured has been increased to provide the necessary assurance of engine availability for the support of the flight program and ground testing. Four additional engines, 2028–2031, will be fabricated, plus long-lead materials for critical components, allowing for potential future fabrication of one or more engines have been added. In addition, the production and engine overhaul schedules have been accelerated. The revised SSME development, certification and acceptance test requirements will fully utilize the three existing single engine test stands. A 1985 Construction of Facilities project is included in this budget to modify the main propulsion test (MPT) stand at the National Space Technology Laboratories to provide capability for single engine testing. This stand will be used initially to meet high pressure turbopump green run requirements which have increased due to the lower than anticipated mean time between replacement and the accelerated spare pump deliveries. A major replacement and upgrading to engine manufacturing machine tools has been initiated jointly by NASA and Rocketdyne to improve production efficiency and quality. Funding has also been included to provide a "test bed" engine by overhauling an existing engine. This engine will be used in concert with the OAST engine technology activities to provide a thorough mapping of the engine environment using improved sensors developed by the OAST program. In addition, design improvements generated through the engine technology studies will be tested on this engine. The selection of an engine testing site is still under review, but consideration is being given to utilization of an existing site at the Marshall Space Flight Center. Modification of a facility for this purpose would be a future facilities project not included in the current budget request.

Additional SRB design improvements are required to reduce the damage being incurred during booster water impact. Although the effort to strengthen the aft skirt structure has been effective in minimizing structural damage, continued damage is being experienced with the thrust vector control system. Improvements to this system are being studied. In addition, since water impact damage is dependent upon the velocity at impact, development of larger main parachutes has been initiated. The new high performance motor

was successfully flown on the STS–8 flight, although post-flight inspection indicated that erosion on one of the nozzles was greater than nominal. Modifications in manufacturing procedures and configuration are being evaluated as possible solutions to these recent problems.

The SRB program includes the development of a filament wound composite motor case. This development effort will enable the replacement of the current steel case segments for high performance launches. The performance increase is achieved by a reduction in the Shuttle liftoff weight resulting in a payload capability improvement of approximately 5,000 pounds. Several structural development tests were conducted in 1983 at the subscale, quarter scale, and full diameter configuration levels. The first flight use is planned for late 1985 on the initial Vandenberg launch.

Transition to the production mode in the ET program is well underway. Production readiness activities continue to smooth this transition and favorably improve production capability. The producibility program is already providing substantial cost savings, in many cases greater than original estimates. Rearrangement of existing tools and new tools to eliminate manufacturing "choke points" and smooth the production flow for the buildup to 24 tanks per year has been emphasized.

In systems support, preparations are underway for the test of the engines at FPL in the main proplusion test stand at NSTL in March 1984. This test will provide for a check of the main engines' performance in conjunction with the main propulsion system test hardware mounted in the aft end of the simulated orbiter.

In FY 1985, funding for the SSME provides for those activities necessary to support the orbiter production, flight schedules, and ground testing. Production flows have been adjusted to allow the addition of four new engines, 2028 through 2031, and to accelerate the delivery of engines 2023 through 2027. Other on-going activities also provided for within the SSME budget estimates include flight spares lay-in, anomaly resolution testing, and continued certification and development testing.

In the SRB, efforts will continue on the improvements to the TVC system and other program elements to minimize flight damage and improve turnaround times on reusable hardware. Procurement of manufacturing tools, transportation support equipment, and related items will continue in support of reaching a 24 per year flight rate objective. In the FWC development activity, funding in FY 1985 provides for reusability/refurbishment studies, completion of development testing, and fabrication of the first two flight articles.

In the ET program, enhancement of manufacturing processes to achieve cost reductions will continue through the producibility and production readiness efforts. The major thrust for FY 1985 will be continuing procurement and installation of tools and equipment to support the build-up to a production rate of 24 per year. To increase productivity, improved weld techniques and automated riveting tools are being introduced.

### CHANGES AND SYSTEMS UPGRADING

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Changes and systems upgrading | $15,000,000 |

Management, technical flight experience, and cost reviews of the Space Shuttle program have stressed the need for providing an adequate allowance for changes and modifications which inevitably are required in a large, complex, and technically demanding space system.

The changes and systems upgrading budget represents the estimated requirement for potential changes and systems modifications and unanticipated developments which are not included in the program element budget estimates. Such funds are necessary to provide for programmatic and technical changes, such as modifications to the orbiters to improve flight performance and system reliability, changes and upgrading of ground systems to reduce turnaround time between missions, and replacement/modification of hardware elements to achieve increased operating economies.

As the changes and upgrading requirements are identified and approved, funds are allocated to the appropriate budget account.

The funding requested for FY 1985 will provide for those changes which are considered to have the highest priority. The objectives are to improve reliability, increase operating efficiency, and reduce costs. Changes and upgrading areas of interest include modifications to flight and ground systems; design and development of hardware/software systems which meet requirements for improved safety, reliability, performance and cost-effectiveness; and changes which will reduce operational costs by extending operational life, by facilitating improved mission-to-mission turnaround time, and by improving mission performance margins.

### 2. SPACE TRANSPORTATION OPERATIONS, $1,329,000,000

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Flight operations | $316,000,000 |
| Flight hardware | 758,000,000 |
| Launch and landing operations | 265,000,000 |
| *General reduction* | *−10,000,000* |
| Total | 1,329,000,000 |

Shuttle operations direct appropriated funding is combined with the reimbursements received from other U.S. Government, Commercial, and international users to support the launch and flight operations requirements of the Space Shuttle. During the first full year of Shuttle operations, four missions were flown (STS–5, –6, –7, –8). These missions demonstrated many of the Shuttle's capabilities, including deployments of spacecraft and their upper stages, proximity operations using the remote manipulator extravehicular activity operations, a night landing, and a widening of the Shuttle's performance envelope. In FY 1984, another seven to eight missions are scheduled to be flown. The first of these, the initial flight of a dedicated Spacelab, had both the largest crew and longest flight time experienced to date. Eleven flights are scheduled for FY 1985.

Flight operations is divided into three major elements: mission support, integration, and support. Mission support includes a wide

variety of planning activities ranging from operational concepts and techniques to detailed systems operational procedures and checklists. Integration includes sustaining engineering for cargo analytical integration, systems integration, and operational support. The support element includes base operational support at JSC and system activity at Headquarters and Goddard Space Flight Center (GSFC).

The flight hardware program element provides for the procurement of ET's, solid rocket motors, booster hardware, and propellants; spare components for the SSME, orbiter spares; sustaining engineering and logistics support for the external tank, solid rocket booster, and main engine flight hardware elements; and maintenance and operations of flight crew equipment. Included in the funding request for ET's, solid rocket motors, and boosters are the long lead time raw materials, subassemblies, and subsystems necessary to sustain the production of elements in a consistent manner with the increasing flight rate.

Launch and landing operations provides for the launch preparation and the launch and landing operations of the Space Shuttle and its cargo.

### Flight Operations

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Mission support | $142,500,000 |
| Integration | 72,900,000 |
| Support | 100,600,000 |
| Total | 316,000,000 |

Flight operations is divided into three major areas of activity: mission support, integration and support. Mission support includes a wide variety of planning activities ranging from operational concepts and techniques to detailed systems operational procedures and checklists. Tasks include flight planning, preparation of development system and software handbooks, flight rules, detailed crew activity plans and procedures of MCC and network systems requirements from each flight, and operations input to the planning for the selection and operation of Shuttle payloads. Specific flight planning activity encompasses the flight design, flight analysis, and software activities. Flight design products include conceptual flight profiles and operational flight profiles which are issued for each flight. The flight design task also includes supporting the crew training simulations and development flight techniques. The software activities include the development, formulation, and verification support of the guidance, targeting, and navigation systems software requirements in the orbiter and MCC. In addition, the flight-dependent data located in the erasable memory (mission-to-mission changes) is developed from the flight design process for incorporation into the orbiter software, Shuttle mission simulator, and MCC systems.

The flight operations portion of the Shuttle operations budget provides the maintenance and operation of the onboard avionics software and the mission control systems; maintenance and operations of the training and flight proficiency aircraft and simulators

for crew training; and analysis and generation of the mission planning necessary to conduct and control the mission and instruct the flight crew. Flight operations also includes the sustaining engineering required to integrate all flight elements and to assure systems safety and integrity; the analytical integration of the payloads into the orbiter and the planning to assure compatibility and verification of interfaces; support of crew operations and training programs; and program support at JSC and NASA Headquarters. In addition, orbiter sustaining engineering manpower is required in support of the orbiter vehicle to ensure maintainability, reliability, and anomaly resolution during operations. The operations and maintenance of the SAIL are provided to test and verify the ongoing operations software and hardware modifications. The SAIL operations are funded as well through the engineering and technical base budget element; this core facility is a key element in the capability of the system to investigate and resolve anomalies experienced on the ground or in flight.

Further, flight operations includes the Getaway Special support managed by GSFC, and payload integration activities at KSC, and the flight crew mission requirements and the safety certification at JSC. Included are the additive (to the core engineering and technical base) operations and maintenance support, printing, equipment rentals, and supplies and materials for the base operations activities at JSC. Other activities are the updates to and verifications of flight software, post-flight assessment, and ground turnaround evaluation. In addition, the current estimate includes engineering, testing and quality assurance necessary for system operations, including avionics verification. These functions were transfered from the integration budget.

Integration includes the identification of operational requirements for the design of improved future spacecraft and STS component systems; the development of flight techniques for utilization of these systems; conceptual level profile development and analysis, beginning about two years before the flight; and operational profile development and analysis, accomplished in the period immediately prior to the flight. Analytical integration is performed for payloads in the cargo bay and mid-deck. The current estimate for integration retains this sustaining engineering and payload analytical integration effort and adds the systems integration effort transferred from the support budget.

Support continues to include that portion of JSC base operations support related to Shuttle operations; systems activities necessary for mission planning and execution; the "Getaway Special" payload cannister effort performed by GSFC, Headquarters programs including assessments for agencywide activities; and efforts by the Space Shuttle Project Office associated with system-wide improvements necessary to achieve the planned flight rate and schedule reliability required for mature system operations.

## Flight Hardware

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Orbiter | $153,200,000 |
| Solid rocket booster | 323,900,000 |
| External tank | 280,900,000 |
| Total | 758,000,000 |

The flight hardware program element provides for the procurement of ET; solid rocket motors, booster hardware, and propellants; spare components for the SSME's; orbiter spares; sustaining engineering and logistics support for external tank/solid rocket booster/main engine flight hardware elements; and maintenance and operation of flight crew equipment. Included in the funding request for ET's solid rocket motors, and boosters are the long lead time raw materials, subassemblies, and subsystems necessary to sustain the production of these elements in a manner consistent with the increasing flight rate. Production phasing of these elements is based on the current flight traffic model and is structured to maintain as smooth and efficient a buildup of the production capability as possible. The procurement of some elements of the SRB have been accelerated to reflect the need for additional hardware to protect against hardware attrition and refurbishment problems encountered during flight tests. In the ET, an efficient and nondisruptive production process continues to be developed which enables manufacturing, assembly, and checkout operations to proceed on a basis which allows for timely delivery of flight hardware to the launch site. The orbiter line element includes: SSME overhauls, procurement of replacement spare parts and attendant sustaining engineering; provision for the fixed level of annual support for the liquid hydrogen plant; orbiter spares for replenishment of line and shop replaceable units, and the manpower for supporting this logistics operation; and, replaceable spares, field support, and maintenance of crew-related equipment. Some examples of orbiter spare equipment are fuel cells, tiles for thermal protection, tape recorders, leading edge support structures, wheels, brakes and pyrotechnics. The crew-related equipment activities include support to the pre-flight training and flight usage of the extravehicular maneuvering unit, emergency portable oxygen systems, radiation instrumentation, survival radios, closed-circuit television cameras, and food and other galley-related items.

Orbiter flight spares, crew equipment spares, and logistics are based on calculations involving flight rates, maintenance schedules, operational hours, turnaround times, and lead times to procure spares. The budget provides replenishment line and shop replaceable units, as well as the manpower to support the overhaul and repair activity required to support the project flight rate. Main engine hardware provides for manufacturing and delivery of overhauled engines and engine component spares. Engine overhaul cost has increased to allow for the staggered removal and earlier than planned overhaul of the engine in the near term. Flight hardware requirements for the SRB and ET include the procurement of the materials and labor required for refurbishment and fabrication of units which will be flown after FY 1985, as well as supporting the production of units which will be flown in that year. Deliveries planned for FY 1985 include thirteen sets of SRB's and twelve ET's.

## Launch and Landing Operations

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Launch operations | $215,300,000 |
| Payload and launch support | 49,700,000 |
| Total | 265,000,000 |

Launch and landing operations provides for the launch preparations and the launch and landing operations of the Space Shuttle and its cargo. The orbiter, external tank, solid rocket boosters, main engines, and payloads are checked out, integrated, and launched from KSC at Cape Canaveral, Florida. The SRB's are retrieved from the Atlantic Ocean after separation from the Shuttle. Space Shuttle landing support is furnished at KSC and contingency landing sites as required. The major facilities used for launch and landing operations include: the launch control center, orbiter processing facility, vehicle assembly building, mobile launcher platforms, SRB processing and storage facility, payload processing facilities, launch pads, and the Shuttle landing facility.

Funding for launch and landing operations provides the propellants, ground support equipment, and manpower required to acomplish the integration and processing of the Shuttle and its payloads. Under launch operations, manpower is provided to process, integrate, and check out the orbiter, ET, solid rocket motors/boosters and the SSME into the proper launch configuration preparatory to each flight. Support manpower is also included to conduct the SRB retrieval operations, engineering support, logistics, central data system support, facility and equipment modifications, and the maintenance and operation of the ground systems, structures and equipment. Funding for payload and launch support provides for the processing and integration of the payloads, procurement of spares for ground support equipment, propellants for launch operations and base support (excluding SRB propellants), and Shuttle operations at the Dryden Flight Research Facility.

During FY 1983, KSC successfully processed the first four Shuttle operational launches and landings. During FY 1984, KSC will process seven to eight launches; the first landing planned at KSC's Shuttle landing facility is among these and will be the first of five KSC landings planned for the fiscal year. The STS flight rate is planned to increase to 24 per year by FY 1989, twenty of which may be from KSC and the remainder from Vandenberg. The first flight from Vandenberg is planned for late 1985.

The contracting philosophy for the operations era has been directed toward the consolidation of contracts to strengthen the STS launch function. Clear contractor responsibility is provided through reducing the interfaces that exist today. NASA is placing more emphasis on the contractor's approach to the job and an overall reduction of many of today's approval requirements, detailed instructions, and daily serial involvement in the work. These changes are expected to achieve cost reductions and to provide the contractors with incentives to achieve future economies while maintaining safety of flight.

To this end, a base operations contract (BOC) was awarded in early FY 1983 to establish a single on-site, consolidated support

contractor to provide institutional support to the KSC organizations. The Shuttle processing contract (SPC) was awarded in late FY 1983 establishing one consolidated contractor for launch and landing activities and operation of related ground systems at both KSC and Vandenberg. There are plans to incorporate a consolidated cargo processing contract (CPC).

Launch and landing operations funding in FY 1985 provides for manpower and support necessary to process the eleven planned launches. This includes manpower to process the build-up of the SRB's, mate the boosters and tanks, process the orbiter, integrate payloads into the orbiter either vertically or horizontally, mate the orbiter, process and check out the integrated flight elements through launch, retrieve the SRB's for refurbishment, and support landing of the orbiter and its return when required from alternate landing sites. Funding also supports the sustaining engineering, logistics, launch processing system, and ground operations and facilities and equipment maintenance, modification and operation. Projected savings due to BOC and SPC efficiencies have been included in the estimate.

Payload and launch support funding provides: propellants for launch operations and base support, spares for the ground support equipment (such as MLP crawler shoes and magnetic tapes for the launch processing system), and contractor support for the assembly of individual payloads into a total cargo. This element includes providing launch site support managers to payload customers, verifying cargo-to-orbiter interface, and providing operations maintenance and logistic support to cargo support equipment—such as cargo integration test equipment and multi-mission payload support equipment—and the payload support areas—such as the Vertical Processing Facility, Operations and Checkout building, and cargo hazardous servicing facilities. Support required for maintaining the Dryden Flight Research Facility as a contingency landing site is also included.

### 3. SPACE AND GROUND NETWORK, COMMUNICATIONS AND DATA SYSTEMS, $780,700,000

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Space network | $386,500,000 |
| Ground network | 223,600,000 |
| Communications and data systems | 185,600,000 |
| *General reduction* | *−15,000,000* |
| Total | 780,700,000 |

The purpose of this program is to provide vital tracking, telemetry, command, and data acquisition support to meet the requirements of all NASA flight projects. In addition to NASA flight projects, support is provided on a reimbursable basis for projects of the Department of Defense (DOD), other Government agencies, commercial firms, and other countries and international organizations engaged in space research endeavors.

Support is provided for sounding rockets, balloons, research aircraft, Earth orbital and planetary missions and deep space probes. The program includes support of the Space Shuttle and Spacelab flight programs. The various types of support provided include: (a)

tracking to determine the position and trajectory of vehicles in space; (b) acquisition of scientific and space applications data from on-board experiments and sensors; (c) acquisition of engineering data on the performance of spacecraft and launch vehicle systems; (d) reception of television transmission from space vehicles; (e) transmission of commands from ground stations to the spacecraft; (f) communication with astronauts; (g) transfer of information between the various ground facilities and control centers; and (h) processing of data acquired from the launch vehicles and spacecraft. Such support is essential for achieving the scientific objectives of all flight missions, for executing the critical decisions which must be made to assure the success of these flight missions and, in the case of Shuttle missions, to insure safety of the crew.

Tracking and acquisition of data for the spaceflight projects is presently accomplished through the use of a worldwide network of NASA ground stations, and by the first of a system of three tracking and data relay satellites in geosynchronous orbit working with a single highly specialized ground station. Ground facilities are interconnected by ground communications lines, undersea cables, and communciations satellite circuits which are leased from communications carriers, both domestic and foreign. This interconnection provides the communications capability needed between spacecraft and the control centers from which the flights are directed.

To meet the support requirements levied by the wide variety and large number of flight projects, NASA has established three basic support capabilities to meet the needs of all classes of NASA flight missions. These are the Spaceflight Tracking and Data Network (STDN), which supports Earth orbital missions; the Deep Space Network (DSN), which supports planetary and interplanetary flight missions; and the Tracking and Data Relay Satellite System (TDRSS), which will provide all low Earth orbital mission support when it becomes fully operational. The STDN will remain the primary Earth orbital support network until three TDRSS spacecraft are launched, properly positioned, and have compieted pre-operational testing to ensure reliablle mission operations support.

When the TDRSS is fully operational, a phaseout of selected STDN ground stations will be initiated. This is presently planned for the first half of 1985. Certain facilities of the STDN will be retained to provide support to geosynchronous and highly elliptical missions which cannot be supported via the TDRSS or to provide launch and Shuttle landing support. These remaining facilities, except for the launch and Shuttle landing support facilities, are to be consolidated with the DSN stations under the management of the Jet Propulsion Laboratory (JPL). The consolidation, when completed, will provide a single network to support geosynchronous, highly elliptical, and planetary missions. The consolidated network will also support those spacecraft, now in low-Earth orbit, which are not compatible with TDRSS.

Computation facilities are maintained to provide real-time information for mission control and to process into meaningful form the large amounts of scientific, applications, and engineering data which are collected from flight projects. In addition, instrumentation facilities are provided for support of sounding rocket launchings and flight testing of aeronautical research aircraft.

The Space Flight, Control and Data Communications appropriation includes the Space Network, Ground Network and Data Processing and Communications elements of the program, and provides funds for: (a) the cost of TDRSS service; (b) operations and maintenance of the tracking, data acquisition, mission control and data processing facilities; and (c) the engineering services and procurement of equipment to sustain and modify the various systems to support continuing, new, and changing flight project requirements. The Research and Development (R&D) appropriation includes the Advanced Systems program element and provides funds for the investigation and development of advanced tracking and data acquisition systems and techniques.

## Space Network

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Tracking and data relay satellite system | $319,900,000 |
| Space network operations | 40,800,000 |
| Systems engineering and support | 25,800,000 |
| Total | 386,500,000 |

The Space Network consists of the Tracking and Data Relay Satellite System (TDRSS) and a number of NASA ground elements to provide the necessary tracking, telemetry, command, and communication services to low Earth orbital spacecraft. The TDRSS itself will consist of a three-satellite system in geosynchronous orbit and a single ground terminal located at White Sands, New Mexico. The satellites communicate with the user spacecraft in space and relay information to and from the terminal. From the ground terminal, satellite and ground communication links interconnect the NASA elements of the network and any remotely located user facilities.

The FY 1985 request includes funding for: repayment of the loans extended by the Federal Financing Bank (FFB) for TDRSS development; payments to the TDRSS contractor for continuing TDRS production, TDRSS services and for maintenance and operation of the White Sands Complex; manpower and services necessary to operate and maintain the other NASA elements of the network; and systems engineering, engineering analyses and other support services to the network elements, such as mission planning, logistics, and documentation.

*Tracking and data relay satellite system*

The Tracking and Data Relay Satellite System (TDRSS) objective is to provide communication services between the user spacecraft and ground facilities. The Tracking and Data Relay Satellites (TDRS) provide space-to-space communications to and from the user satellites and relay these communications to the ground via a single ground terminal which is interconnected with the other elements of the Space Network. From their position in geosynchronous orbit, the TDRS can provide nearly a six-fold increase in the orbital coverage provided by the existing complex of ground stations and can accommodate extremely high user data rates ranging up to 300 megabits per second. These capabilities will provide

tracking, command, telemetry, and communication services to the flight missions of the Shuttle era.

The TDRS–1 was launched in April 1983, and the Inertial Upper Stage (IUS) booster failed to deliver the TDRS spacecraft into the correct orbit. In late June, the mission was recovered through a complex sequence of maneuvers, and the spacecraft was placed into its nominal orbit. Since that time, the spacecraft has supported subsequent Shuttle missions, including Spacelab–1, while continuing the test and checkout of the TDRSS spacecraft and ground terminal. Recently, the spacecraft has experienced failures of the Ku Band forward link that provides communication from TDRSS to the user spacecraft. The cause of these failures is currently under review.

The launches of TDRS–B and C have been delayed while modifications are being made to the IUS to rectify the causes of the anomaly experienced during the first launch. Current plans anticipate launch of the second TDRS in late 1984 with the third launch following in early 1985. These launches will complete the operational constellation of three TDRS's. Production of TDRSS spacecraft continues with TDRS–B having completed testing and been placed in storage. TDRS–C has completed environmental tests and is being prepared for storage; (some modifications to these spacecraft may be necessary as a result of the TDRS–1 problem) TDRS–D, first of the ground spares, begins environmental testing this spring. The TDRS B–F will have the C–band modification for Government communication use. Principal agencies that plan to use C–band are DOD, NASA and U.S. Information Agency (USIA).

Under the terms of the TDRSS service contract, loans were extended by the Federal Financing Bank (FFB) to the Space Communication Company (SCC), the owner-operator of the TDRSS, for program development. Under the terms of the loan agreement and assignment, NASA repays these loans directly to the FFB. In addition, NASA will make payments to SCC for TDRSS services, for continued spacecraft production, for maintenance and operation of the White Sands Ground Terminal and other support to be provided during the year. Current planning provides for launch of the initial four spacecraft (TDRS–1 and –B through –D) using the IUS and the launch of TDRS–E using the Centaur/STS upper stage. The activities associated with integrating the TDRS with the Centaur/STS upper stage will be initiated in FY 1985.

Of the amount requested in FY 1985, $210 million is for loan repayments to FFB, $33 million for the impact of the IUS anomaly, $36 million for continuing TDRSS production and the balance of the request for TDRSS service payments, maintenance and operation of the White Sands Ground Terminal, TDRSS integration with the Centaur upper stage, and other changes and support activities. These estimates are predicated upon the successful launch and checkout of TDRS–B and TDRS–C in November 1984 and February 1985, respectively.

*Space network operations*

The objective of Space Network Operations is to provide for the operation and maintenance of the associated NASA ground systems which, when combined with TDRSS, provide a full array of

reliable tracking, telemetry, command, and communication services to user spacecraft in low-Earth orbit. Each of these NASA systems perform specific functions for the Space Network.

The NASA Ground Terminal (NGT) monitors TDRSS performance and provides fault isolation monitoring for the network. The Network Control Center (NCC) schedules TDRSS services for all user spacecraft, and the Operations Support Computing Facility (OSCF) provides orbit determination, trajectory analysis, and position location for flight missions supported either via the Space Network or by the current Spaceflight Tracking and Data Network (STDN). The Bilateration Ranging Transponder System (BRTS) provides precision position location and orbit determination for the TDRS. The Simulation Operations Center (SOC) and the Compatibility Test Vans (CTV) provide necessary pre-launch testing, simulations, and interface verfication for both user spacecraft and the various network elements to assure the operational readiness of the network to support a given mission.

The individual elements are designed to function as an integrated operational system. Currently, the overall system is in an integration and test phase and is providing service to the user community on a limited basis. Effort is also continuing on achieving an operational configuration that is capable of supporting an expanded workload in the late 1980's.

The funding request provides for contractor personnel to operate the network systems 24 hours per day, seven days per week, and to provide requisite hardware and software maintenance. A contract has been competitively awarded to provide these operations and maintenance services. In addition, a variety of support services is provided in the areas of logistics, mission planning and documentation.

*Systems engineering and support*

The objective of System Engineering and Support is to provide the engineering services and requisite hardware systems to implement and sustain the NASA elements of the Space Network. Engineering services are supplied primarily through the operations contract and a number of small, highly specialized engineering service contracts. Current emphasis is on the completion, test, and integration activities in preparation for the initial operations of the Space Network. Activities include test scenario design and development, system and subsystem level troubleshooting during simulations, end-to-end network testing, and operations procedure development.

Requested funding will provide for engineering support under the operations mission contract in the areas of systems engineering, performance and operation analyses, minor facility modifications, and network integration testing and interface verification. In addition, other contractors will supply sustaining engineering support, test equipment, and vendor maintenance for specialized equipment and subsystems within the Space Network. Design and analytical studies will be conducted on a wide array of items ranging from subsystem modifications to meet new mission requirements or to correct system deficiencies to the analysis of the radio frequency environment for potential impact on TDRSS and other network systems. Funds are also requested for continued software

development for the NCC Full Operational Capability (FOC) and to complete procurement of replacement high data rate switching systems for the NASA Ground Terminal (NGT).

## Ground Network

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Spaceflight tracking and data network systems implementation | $6,300,000 |
| Spaceflight tracking and data network operations | 83,300,000 |
| Deep space network systems implementation | 37,100,000 |
| Deep space network operations | 76,800,000 |
| Aeronautics, balloons and sounding rocket support systems implementation | 8,200,000 |
| Aeronautics, balloons and sounding rocket support operations | 11,900,000 |
| Total | 223,600,000 |

The Ground Network includes the Spaceflight Tracking and Data Network (STDN), consisting of 15 geographically dispersed ground stations which support Earth orbital missions; the Deep Space Network (DSN) consisting of three stations approximately 120 degrees apart in longitude, for continuous viewing, which supports planetary and interplanetary flight missions; and support for Aeronautics, Balloon and Sounding Rocket (AB&SR) programs at the Wallops Flight Facility (WFF), the Dryden Flight Research Facility (DFRF), the Moffett Field Flight Complex (MFFC), and White Sands Missile Range (WSMC), as well as instrumentation support at the National Balloon Facility at Palestine, Texas.

Funding for the ground network provides for operation and maintenance of the worldwide facilities, as well as engineering and procurement of equipment to sustain and modify network systems. The workload in FY 1985 includes ongoing support to Shuttle, Voyager, Dynamic Explorer, International Ultraviolet Explorer (IUE), and the International Sun-Earth Explorers, as well as preparation for support of such upcoming missions as Galileo, the Voyager-Uranus encounter, and the Venus Radar Mapper (VRM). Support will be provided to aircraft programs such as the F-16 and F-111, AV-8B, the forward swept wing, and the use of drones for aerodynamic and structural testing.

The FY 1985 budget request reflects a continuation of STDN ground station operations for six months into FY 1985 and then a planned phaseout of most of the ground stations after TDRSS is operational. This extension of STDN operations over previous plans is due to the rescheduling and delay of the TDRS-B and -C launches resulting from modifications that must be made to the IUS as a result of the problems experienced during the launch of TDRS-1. Three of the remaining STDN facilities will be consolidated with the DSN stations under management of the Jet Propulsion Laboratory (JPL). The consolidation will result in a single network to support geosynchronous, highly elliptical, and planetary missions. The remainder will be dedicated to support of launch and Shuttle landing operations and for scientific satellites such as IUE, IMP-8 and Nimbus 7.

*Spaceflight tracking and data network systems implementation*

The Spaceflight Tracking and Data Network (STDN) systems implementation program encompasses the procurement and implementation of services to sustain network facilities and equipment to insure reliable tracking, command, and data acquisition support to ongoing scientific and applications satellite missions and the Space Shuttle, and to selectively replace obsolete equipment for reliable support in the TDRSS era. Employing systems implemented in past years, the network is currently supporting many missions with highly complex requirements for tracking, data acquisition, command and control.

The FY 1985 request includes funds for the replacement of obsolete and difficult-to-maintain equipment at those facilities that remain after TDRSS is operational. These include facilities used for launch support at Bermuda, Merritt Island, Florida and New Smyrna Beach, Florida, and for orbital support from Greenbelt, Maryland. The requirement for support from these sites will continue for the foreseeable future. Equipment replacements and modifications are required in the network in FY 1985 to maintain a level of proficiency to support the continuing workload and to assure the reliability of the major systems. Accordingly, funds are required for equipment replacements and modifications to correct current deficiencies, and for equipment to be used in operational control of the network. The funds requested also provide for procurement of major subsystem spares, for the provision and modification of test equipment, and for minor equipment modifications resulting from changes in support requirements.

*Spaceflight tracking and data network operations*

The primary function of the Spaceflight Tracking and Data Network (STDN) system is to support all NASA Earth-orbital spaceflight missions, including the Space Shuttle. The majority of these missions have near-Earth orbits; however, the network also supports selected missions through lunar distances and beyond, such as the International Sun-Earth Explorer (ISEE) missions. In addition, the network provides launch support to NASA automated planetary missions, and on a reimbursable basis, spaceflight missions of other nations, commercial firms, and other United States government agencies. Accordingly, the network must be responsive to the requirements of a large number and wide variety of flight projects from launch through completion of the flight project objectives. In many instances, the period of network support required by flight projects continues for several years.

The STDN presently consists of 15 geographically dispersed ground stations. These global facilities have the capability to electronically track the spacecraft, send commands for spacecraft and experiment control purposes, receive and display engineering and scientific data from the spacecraft, and in the case of manned flights, maintain voice communications for crew operations and safety, and other project-related purposes.

There are 12 STDN land stations located at: Fairbanks, Alaska; Goldstone, California; Greenbelt, Maryland (GSFC); Merritt Island, Florida; Kauai, Hawaii; Guam; Ascension Island; Canberra, Austra-

lia; Dakar, Senegal; Bermuda; Santiago, Chile; and Madrid, Spain. In addition to these 12 stations, three additional facilities supplement the STDN, primarily for Space Shuttle support. A small station is located at New Smyrna Beach, Florida, for support of Shuttle launch and landings. Also, two UHF/voice air-to-ground stations are located at Gaborone, Botswana and Yarragadee, Australia to provide additional voice coverage with the astronauts. An Air Force station in the Indian Ocean is occasionally used to provide additional Shuttle support.

The FY 1985 funding requirements provide for the maintenance and operation of the STDN until phasedown begins in the April 1985 time period. This represents a planning assumption which is contingent upon the successful launch and checkout of the remaining two TDRS (-B and -C). Included in the funding request are the related logistics support, network planning, scheduling, engineering, documentation and software programming costs associated with the operation of the network.

The initiation of full TDRSS service will permit closure of several STDN stations in FY 1985—Ascension, Guam, Hawaii, Santiago, Dakar and Botswana—and the termination of Tracking and Data Acquisition activities at the Air Force Indian Ocean station and Yarragadee, Australia.

*Deep space network (DSN) systems implementation.*

The role of the Deep Space Network (DSN) is to provide the communication link between each of NASA's distant planetary and interplanetary spacecraft and the Earth. The DSN is responsible for receiving science and engineering data, and providing the navigation, command and control capabilities from the ground to a constellation of spacecraft ranging in distance to over 4.6 billion kilometers from Earth. After the Tracking and Data Relay Satellite System (TDRSS) becomes operational, the DSN will also support spacecraft much closer to Earth. The new set of spacecraft support requirements will include missions in highly-elliptical and synchronous Earth orbits which are not supportable by the TDRSS.

The systems and facilities required to support spacecraft at the limits of the solar system are highly specialized and include the use of large aperture antennas electronically configured in a phased array for optimum reception of the extremely weak radio signals. The antennas use ultrasensitive, cryogenically cooled receivers and powerful transmitters. Extremely stable hydrogen maser time standards are required for precise navigation of distant spacecraft. Advanced data handling systems are required at both the DSN complexes and the Network Operations Control Center (NOCC).

The four major objectives for the DSN is the 1980's are as follows: (1) to provide communications channels to scientific spacecraft at ever-increasing distances and to provide the capability to receive images at these great distances; (2) to consolidate the activities of the residual Spaceflight Tracking and Data Network (STDN) with the DSN after the TDRSS becomes fully operational in 1985; (3) to provide support for a new set of spacecraft which will include highly elliptical Earth orbiters and synchronous Earth orbital missions (both types will be in orbits at altitudes that are beyond the

support area of TDRSS); and (4) to provide the improved navigation capabilities required for precise spacecraft targeting and probe delivery.

These objectives represent a significant challenge to the DSN, as it will be supporting many more spacecraft than in the past, and it will be working at extremely great distances (beyond the orbits of the known planets) by the end of the decade.

The next major planetary encounter will be of Uranus by Voyager-2 in 1986. This encounter will occur some 2.9 billion kilometers from Earth. At that time, Voyager-2 is expected to transmit the first high resolution images ever received from a spacecraft at such a distance. The newly consolidated network will receive its first major test on compound multiple antenna arraying (more than two antennas) during this Uranus encounter. In Australia, this will include the use of the 64-meter antenna of the Australian commonwealth Scientific and Industrial Research Organization (CSIRO). Further, the follow-on Neptune encounter by Voyager-2 in 1989 will require even greater antenna apenture. An expansion of the 64-meter antennas to 70-meter, along with compound multiple antenna arraying, will provide the increased signal capturing capability for our first look at this planet. In addition, the design and implementation of the new consolidated network must provide the flexibility necessary to support older near-Earth missions that are not compatible with the TDRSS. To support these older spacecraft in their extended mission phase, and to provide backup support to the TDRSS itself, existing 26-meter STDN antennas will be moved and colocated with the DSN facilities at Canberra and Madrid.

Upcoming deep space missions which will be supported by the network in the 1980's include the Jupiter orbiter and probe (Galileo), the International Solar Polar Mission (ISPM), and the Venus Radar Mapper (VRM). One or more of the Halley's Comet rendezvous missions will also be supported for the international community.

Funding in the FY 1985 request provides for continuing the reconfiguration of the ground network facilities into a consolidated, modern, and highly reliable network. The capabilities planned in the reconfiguration will provide for enhanced spacecraft-ground telecommunications and navigation precision while reducing overall maintenance and operations costs. Equipment required for this capability includes antenna monitor and control equipment, and receiving and data handling systems along with the necessary engineering and fabrication. Some equipment will be provided to augment the Parkes Antenna in Australia to properly handle and combine the signals received during the Voyager-Uranus encounter at that location.

In addition, funds are included for implementing a central signal processing center at each DSN complex. Instead of independent support facilities for each antenna, it will be posible to support all antennas at each complex from a central operations center. This center will include the digital electronics required for uplink command encoding, downlink demodulation, signal recording, and data transmission for all the antennas in the complex. Centralized, shared maintenance and support facilities will also be provided.

The overall design will allow antennas to operate either independently (with different individual spacecraft) or in an arrayed fashion (more than one antenna targeted on a single spacecraft) to achieve the increased aperture necessary to support the high data rate of missions such as Voyager 2 at Uranus and Neptune. As the distance to the spacecraft doubles, the antenna aperture needed to provide an equivalent signal goes up by a factor of four, resulting in the need for extremely sensitive receiving equipment as well as increased antenna aperture.

In conjunction with the evolution of the consolidated network, modifications are planned at the Network Control Center to facilitate scheduling, spacecraft acquisition and tracking, monitor and control, and overall coordination of the activities of the network. Funding also provides for continued development and improvement of in-flight navigation accuracy.

Concurrent with these important engineering changes, FY 1985 funds will be required to maintain the high level of reliability for support of time-critical spacecraft maneuvers, as well as routine ongoing support. This will be accomplished through a continuing program of equipment and facility refurbishment and modifications to assure compatibility of existing equipment with the new system being implemented in the network.

*Deep space network operations*

The three Deep Space Network (DSN) complex locations—Goldstone, California; Canberra, Australia; and Madrid, Spain—are approximately 120 degrees apart in logitude and permit continuous viewing of planetary spacecraft. Each complex currently consists of one 64-meter and one 34-meter diameter antenna; an additional 34-meter antenna is being constructed both at Goldstone and Canberra.

A centralized control center for the network is located at the Jet Propulsion Laboratory (JPL) in Pasadena, California. JPL has field responsiblity for the network. Separate contracts exist for the operation of the Australian, Spanish, and Goldstone sites. The contract for the Goldstone station also includes network support activities and operations of the Network Control Center at JPL.

The expected workload in 1985 on the DSN consists of the two Voyager spacecraft, the seven ongoing Pioneer spacecraft (Pioneer 6–11 and Pioneer Venus), Active Magnetoshere Particle Tracer Explorer, International Sun Earth Explorer-1 and -2, Helios-1, Nimbus-7, Design Engineer, Geosyncronous Operational Environmental Satellite, and the International Sun Earth Explorer-3 encounter with the Comet Giacobini-Zinner. Provision is also being made in the DSN to provide TDRSS emergency support.

The Voyager-2 spacecraft is on a trajectory for an encounter with Uranus in early 1986, and should provide the first detailed information on that distant planet. Voyager-1 is now about 2.8 billion kilometers from Earth on a trajectory that will take it out of the solar system. Of the older Pioneer spacecraft, Pioneer-10 is now beyond the orbit of Pluto and therfore is the first man-made object to leave the solar system. It now takes nearly eight and one-half hours for a radio signal, traveling at the speed of light, to make the round trip between Earth and Pioneer-10. The Pioneer-11 space-

craft, some 2.4 billion kilometers from Earth, continues to be tracked. The Pioneers-6–9 spacecraft are provided support during solar conjunctions and gravity wave experiments. The helios-1 mission is continuing its orbit about the Sun.

The DSN facilities are also used on a noninterference basis for ground based measurements in support of experiments in planetary radar mapping and in the field of radio astronomy. The ultrasensitive network antennas are being used in an attempt to learn more about the mysterious pulsar high energy sources, quasars, and other interstellar and intergalactic phenomena.

In addition to the activities associated with network modifications and the support cited above, the DSN operations workload includes preparation for the Galileo spacecraft (the mission to Jupiter) and Giotto (the reimbursable European Space Agency (ESA) mission to Halley's Comet). This support preparation requires thorough and complex testing, training, and engineering involving both hardwares and software. These activities must be carried out simultaneously with the extensive ongoing DSN workload, and must be done in such a way as to cause minimum disruption to ongoing flight project support..

In preparation for the Voyager-2 encounter with Uranus, an additional 34-meter antenna is being constructed at both Goldstone and Canberra. These antennas will be electronically combined with the other facilities at their respective complexes so as to further increase the receiver gain available at these two stations which are both key to capturing imaging and remote science data from Uranus. The DSN complex at Canberra, because of its southern hemisphere location, will have the best view of Voyager-2 at Uranus. At that location, an additional facility will be used at the time of encounter; that facility is the Australian 64-meter Radio Observatory at Parkes, which will be electronically combined with an array of DSN antennas. ESA is planning to use this same radio observatory facility in support of their Giotto mission to Halley's Comet. The arrival of Giotto at Halley's Comet at a time close to the Voyager-2 Uranus encounter will require close coordination between NSA, the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, and ESA in order to assure success.

The DSN operations funding provides for the maintenance and operation of the network facilities, control center, and the support and engineering effort associated with continuing operation of the network. Funds requested for FY 1985 are based upon the ongoing workload, including the Voyager missions, Pioneer 6–11 missions, Pioneer-Venus extended mission, Helios mission, the preparation required for the upcoming activities mentioned above, and the assumption of management and funding responsibility for the consolidated network. The transfer of STDN facilities and management responsibility for the consolidated network to JPL in early 1985 is the primary reason for the funding increase from FY 1984 to FY 1985.

*Aeronautics, balloons and sounding rocket support systems implementation*

The objective of the Aeronautics, Balloons, and Sounding Rocket (AB&SR) Support Systems Implementation program is to provide fixed and mobile instrumentation systems to meet the tracking, data acquisition, and range safety requirements of the aeronautical research conducted at the Wallops Flight Facility (WFF) in Virginia, the Dryden Flight Research Facility (DFRF) in California, the Moffett Field Flight Complex (MFFC) in California, and the scientific investigations conducted with balloons and sounding rockets at Wallops, the White Sands Missile Range, New Mexico; Poker Flats, Alaska; Palestine, Texas and other selected sites around the world.

The aeronautical research efforts and scientific experiments using sounding rockets and balloons are programs of a continuing nature which generally require about the same level of support from year to year. To support these programs, WFF provides fixed and mobile instrumentation systems; namely, radar, telemetry, optical, communications, command, data handling and processing systems. To maintain these facilities, replacement parts must be acquired, and test and calibration equipment routinely replaced.

Due to the age of some of the radar, telemetry, and impact prediction equipment, a phased replacement and refurbishment program is underway to insure reliable real-time data collection and handling support to meet current and future requirements.

Funds are also included in the budget request for implementation of a second directional UHF antenna system at the DFRF as a part of the overall effort to develop a capability to support two missions simultaneously in order to accommodate the increase in flight research activity of that facility. Telemetry data processing equipment will be replaced at MFFC and radar data processing equipment will be replaced at both DFRF and MFFC. At WFF, the major expenditure is for rehabilitation of the FPQ–6 radar which supports aeronautics and balloon research activities as well as rocket launches.

*Aeronautics, balloons and sounding rocket support operations*

Fixed and mobile instrumentation systems are maintained and operated to support sounding rocket, balloon, spacecraft, and aeronautical programs conducted by the Wallops Flight Facility (WFF), the Ames Research Center (ARC) at its Dryden Flight Research Facility (DFRF), and Moffett Field Flight Complex (MFFC). These instrumentation systems include radar, telemetry, data processing, data handling, and communications systems, as well as special purpose optical equipment.

The Sounding Rocket program continues to be an active program with approximately 200 launches in FY 1983, the majority of which were conducted at WFF. IN addition, there were over 45 large scientific balloon flights, along with approximately 130 smaller special purpose balloon flights during the same period. At WFF, the aeronautical programs are primarily related to investigation of aircraft handling characteristics, advanced control and display concepts, spin and stall tests, terminal area guidance and traffic control systems, and storm dynamics studies. The year 1983 was very

active with over 300 research missions conducted during that period. In addition to support of sounding rocket, balloons, and aeronautical programs, instrumentation at WFF will continue to be utilized to support the Shuttle orbital flights.

ARC operates aeronautical test ranges at DFRF and MFFC which provide radar, telemetry, optical, and communications support for the performance of aircraft research and development programs. A variety of programs are conducted at these facilities involving high performance aircraft, such as the F-111, F-14, F-16, F-104, F-8, and unique research vehicles such as the tilt-rotor research aircraft, quiet short-haul research aircraft, composite rotorcraft, X-wing aircraft, and drones for aerodynamic and structural testing. Over 400 aeronautical research missions were supported at DFRF and nearly 300 at MFFC during FY 1983. DFRF was the prime landing site for STS-5, -6, -7, -8 and -9. Tracking and data acquisition support of Shuttle orbital flights will continue in the future. The MFFC operations are funded through FY 1984 in the appropriation for Aeronautics programs. In late 1983, it was decided to transfer the management responsibility for MFFC from the Office of Aeronautics and Space Technology to the Office of Space Tracking and Data Systems.

The FY 1985 funding requirements provide engineering and technical services for maintenance and operation of fixed and mobile radar, telemetry, optical, communications, and data handling and processing equipment and facilities to support the ongoing sounding rocket, balloon, and aeronautical research activities. The effort funded represents a continuation of the baseline support provided to the aeronautics, balloons, and sounding rocket program. The increase in funding level from FY 1984 to FY 1985 reflects the transfer of responsibility of the Moffett Field Flight complex from the Office of Aeronautics and Space Technology to the Office of Space Tracking and Data Systems.

### Communications and Data Systems

FISCAL YEAR 1985 FUNDING LEVEL

| | |
|---|---|
| Communications systems implementation | $6,500,000 |
| Communication operations | 68,200,000 |
| Mission facilities | 12,400,000 |
| Mission operations | 21,900,000 |
| Data processing systems implementation | 26,600,000 |
| Data processing operations | 50,000,000 |
| Total | 185,600,000 |

Funds requested for the Communications and Data Systems program provide for the implementation and operation of facilities and systems which are required for data transmission, mission control, and data processing support.

Communication circuits and services are necessary to transmit data between the remote tracking and data acquisition facilities, launch areas, and the Mission Control Centers. Real-time information is crucial to determining the condition of the spacecraft and payloads for the generation of commands for spacecraft and payload control. Data received from the various spacecraft must be processed into a usable form before transfer to control centers and

experimenters. Such support is mandatory for achieving mission objectives. Missions supported include Shuttle, NASA scientific and application missions and international cooperative efforts.

*Communications systems implementation*

The objective of the Communications Systems Implementation Program is to provide the necessary capability in NASA's Global Communications Network (NASCOM) to meet new program support requirements, to increase the efficiency of the network, and to keep NASCOM at a high level of reliability for the transmission of data. NASCOM interconnects the tracking and data acquisition facilities which support all flight projects; it also links such facilities as launch areas, test sites, and mission control centers.

The major effort underway in the NASCOM is the procurement and implementation of a digital replacement voice and data message switching system at the Goddard Space Flight Center (GSFC).

The FY 1985 funding requirements will provide the sustaining equipment and modifications to support the NASCOM network and initiate procurement of a replacement digital voice and data message switching system at GSFC. Implementation will continue on the use of advance digital techniques for Time-Division-Multiple-Access (TDMA) via satellite and on the use of fiber optic cables for high data rate distribution in support of Spacelab and Space Telescope.

*Communications operations*

NASA's Global Communications Network (NASCOM) interconnects, by means of leased voice, data, and wideband circuits, the tracking and data acquisition facilities which support all flight projects. NASCOM also links such facilities as launch areas, test sites, and mission control centers. Goddard Space Flight Center (GSFC) operates the NASCOM and serves as its major switching control point. In the interest of economy, reliability, and full utilization of trunk circuitry, subswitching centers have been established at key domestic and overseas locations. The NASA flight projects require the transfer of data between the mission control centers and the tracking sites because of the need for real time control of spacecraft and on-board experiments. In addition, there are requirements to provide experiment data expeditiously to users for analysis.

NASA's Program Support Communications (PSC) interconnects by means of leased voice, data, and wideband circuits the NASA Centers, Headquarters, and major contractor locations for the transfer of programmatic and administrative information. Marshall Space Flight Center (MSFC) operates the PSC and serves as its major switching control point.

In order to meet high data transfer rate requirements, NASA has implement and will continue to use digital and other newly developed techniques in providing communications support. The continuing availability of new technology provides for the transmission of increasing amounts of data in a cost effective and highly reliable manner.

The fiscal year 1985 funding requirements for Communications Operations will provide the circuits and service required to operate

and maintain the NASA Global Communications Network. International communications satellites and cables will continue to be used to provide digital wideband services to all the overseas tracking stations. The domestic satellite systems and terrestrial networks will continue to service the continental United States stations. These services will provide for real-time transfer of data for all ongoing flight programs.

In addition, funds are included for Program Support Communications (PSC) which provide for the circuits and facilities for programmatic and day-to-day operations such as facsimile, teleconferencing, data transmission, and computer-to-computer data sharing for NASA centers and Headquarters. In fiscal year 1985, funds are required to implement the PSC Network gateway equipment which will provide direct connections to the network from all NASA centers and Headquarters. Funding increases in fiscal year 1985 are due to programmatic requirements for additional dedicated data circuits for Spacelab payloads, Space Telescope, and the Space Transportation System management information system.

*Mission facilities*

The Mission Facilities implementation program provides the systems capability for the command and control of NASA's unmanned scientific and applications satellite programs. Command and control of the spacecraft and on-board experiments is carried out via the Payload Operations Control Centers (POCC's) and related Mission Support Systems (MSS).

The POCC's are responsible for the receipt, processing, and display of spacecraft engineering data and the transmission of commands. Four POCC's currently monitor and control numerous spacecraft. In addition, a new dedicated control center is being implemented to control the operations of the Space Telescope to be launched in fiscal year 1986. Related Mission Support Systems include a Johnson Space Center/Goddard Space Flight Center Shuttle POCC Interface Facility and a closed-circuit television and data communications system.

The FY 1985 funding requirements will provide for the continuing development of the Space Telescope Operations Control Center. Two major activities, the Preliminary Operations Requirements and Test System (PORTS) and Payload Applications Software System (PASS), plus a test and validation effort will be underway to meet the FY 1986 launch date. The control center hardware installation will have been completed and integration testing with the spacecraft on the ground will be conducted. Also, the control center hardware and software will be interfaced to the worldwide tracking and data systems for contingency support. The off-line software which provides the high precision telescope pointing, manipulation of the cameras and spectrographs, pointing of the spacecraft antenna toward the TDRSS, and energy and momentum management of the vehicle itself, will require additional development and testing. Funds are also necessary to assure that the PORTS, PASS, and Data Capture Facility operate as in integrated system.

In addition, FY 1985 funds will provide for modifications to the existing Multisatellite Operations Control Center (MSOCC) for control of the upcoming Gamma Ray Observatory (GRO) and Cosmic

Background Explorer (COBE) spacecraft, and for sustaining activities such as changes to interface devices and replacement of obsolete equipment.

*Mission operations*

The Mission Operations Program provides for the operation of four Payload Operations Control Centers (POCC's), a Mission Operations Center, and the related software and support services necessary for the monitoring and control of 10 in-orbit spacecraft.

The POCC's, which are the control facilities for spacecraft/payload operations, contain all of the necessary equipment, software, and personnel needed to monitor, evaluate, and control the performance of spacecraft and experiments. Each POCC is operated 24 hours per day, seven days per week. For shuttle launches with control center payloads, the POCC will issue commands and receive telemetry through the GSFC Shuttle Payload Interface Facility (SPIF). The SPIF will also process a variety of Shuttle-unique data and display these data to the POCC via closed circuit television.

The FY 1985 budget request includes funds to operate the POCC's and supporting facilities for the control of on-orbit missions. Also in FY 1985, POCC and Command Management software development activities will be increasing for both the Cosmic Background Explorer (COBE) and Gamma Ray Observatory (GRO) missions. Software to enable the POCC to work with the consolidated network will be developed and efforts will continue on SPIF software development.

Also included in the FY 1985 budget request are funds for software and related support sevices which include maintenance of a software library, coordination and display of launch data, computer-generated command sequences, equipment maintenance, logistics, documentation, engineering services and operation of a closed circuit television/data communications system.

*Data processing systems implementation*

The Data Processing Systems Implementation program provides for the procurement of equipment and related services for the large data processing and computation systems at the Goddard Space Flight Center (GSFC) which support both the operational and payload requirements of space missions. To meet operational requirements, these systems determine spacecraft attitude and orbit, and generate on-board commands to the spacecraft subsystems. In support of spacecraft payloads, the systems process the data for science and applications experiments for subsequent transfer to the experimenters for analysis.

Significant activities in this program continue at the Goddard Space Flight Center to keep the large systems viable and responsive to project support requirements. The Telemetry On-Line Processing System (TELOPS) is routinely supporting a number of Earth-orbiting spacecraft. The Image Processing Facility (IPF) is generating products for Landsat and Nimbus 7. The Spacelab Data Processing Facility (SLDPF) supported the Spacelab–1 mission very efficiently and will have mission unique changes made that are required to support Spacelab-3 and -2. A new Flight Dynamics System to perform the computations required to determine space-

craft attitude and to execute spacecraft maneuvers was placed on line in mid-1983. Implementation countinues on a new system to process data from numerous and varied experiments which comprise the payloads of early Spacelab missions.

The FY 1985 budget request will provide continued funding for phased replacement of the existing computation systems at the Goddard Space Flight Center which provide real-time support to NASA spscecraft. Included in the support are such critical activities as real-time attitude and orbit determination, memory management for on-board computers, and flight maneuver control. These systems are approximately 18 years old. The system architecture of the existing equipment requires more extensive software development to meet new mission requirements. Replacement is needed because hardware and software maintenance is becoming more difficult and expensive, and more frequent outages are becoming a threat to spacecraft support.

The FY 1985 funding request provides for continuation of the phased replacement program for the command management system and the orbit computation system at GSFC. The orbit computation replacement system will have a complex task of not only supporting free flyer spacecraft, but also the Shuttle and the Tracking and Data Relay Satellite System (TDRSS). Maintaining the TDRSS position accuracy and user spacecraft's relative position determination will impose a significant demand on the orbit computation system resources.

In addition, funds are required to continue the implementation of a stand-alone Space Telescope Data Capture Facility which will capture, error check, and ship scientific data to the Space Telescope Science Institute. The system is necessary to handle the planned "Packet" telemetry concept and to assure support over the long mission lifetime of the Space Telescope. The "Packet" telemetry concept allows the scientific data of an experiment to be handled with minimum involvement by the ground system, thus minimizing ground data processing time as well as insuring faster delivery of data to the experimenters. FY 1985 funds are requested also to continue the development of a general purpose, multimission system to handle packet telemetry with the Gamma Ray Observatory (GRO) as its first user.

Funds are required in FY 1985 for the augmentation of the SLDPF to support missions such as ASTRO–1, –2, –3; Earth Observation missions; and Sunlab. These Dedicated Discipline Laboratory (DDL) missions will be flown more frequently than the earlier Spacelab missions, have a higher average data rate, and require quicker release of experiment data to the scientific community.

There is a continuing requirement to procure and maintain an adequate supply of spare parts to replace failure-prone and high-maintenance electronic modules, to provide test equipment, and to undertake minor modifications and hardware fabrication associated with new equipment installation and reconfiguration.

*Data processing operations*

Information received in the form of tracking and telemetry data from the various spacecraft must be processed into a usable form before transfer to control centers and experimenters. This transfor-

mation and computation process is performed as part of the data processing function and applies to a wide variety of programs, ranging from the small explorer satellites to complex Landsat satellites.

Tracking data is processed to provide orbital information which is used to compute spacecraft position. This is essential for the real time control of spacecraft, for determining when the spacecraft will be passing over the stations so data can be acquired, and for providing precise information that can be used by the scientific experimenters to determine where in the trajectory of the spacecraft the scientific measurements were made. Telemetry data must be processed to separate the information obtained from various scientific experiments aboard the spacecraft, consolidate information for each experimenter, determine spacecraft attitude, and correlate these measurements with the position data. Processed data is the primary product of the spacecraft missions, and it is through reduction and analysis of this data by the experimenters that the planned objectives are achieved.

In addition to the actual processing of the data, upcoming projects require extensive prelaunch orbit analysis including spacecraft position and attitude predictions. Analyses are also required to develop operational sequences and procedures to be used during the actual operation of these complex spacecraft.

As part of the data processing activities, three facilities, the Image Processing Facility (IPF), the Telemetry On-Line Processing System (TELOPS), and the Spacelab Data Processing Facility (SLDPF), have been established at the Goddard Space Flight Center to process different types of raw experimental data.

The IPF, initially established to handle image data from the Landsat-1, has supported Landsat-2 and Landsat-3 and presently is processing residual data from these spacecraft as well as current data from the Nimbus missions. These spacecraft are being supported with an all-digital system using high density recorders and computer campatible tapes. This equipment has reduced the time required to provide data to users as well as the completion of processing of the ten-year Landsat data archive required for climate and meteorological studies.

The Telemetry On-Line Processing System (TELOPS) handles the non-image data. TELOPS receives satellite data in a digital form from the tracking stations via the NASA global communications network lines and is able to electronically store large volumes of telemetry data, thus eliminating most of the tape and tape handling operations. Facility managment, maintenance and operations, and software development support for the image and non-image data processing facilities are also provided. The operations of the Spacelab Data Processing Facility (SLDPF) is included along with software development and maintenance required for attitude determination, flight maneuvers, and mission simulations.

The FY 1985 budget request includes funds to operate the Image Processing Facility (IPF) and the Telemetry On-Line Processing System (TELOPS).

Additional funds will also be required for operations of the SLDPF as the number of Spacelab missions increase and preparations are initiated for the support of the Dedicated Discipline Labo-

ratory (DDL) missions. Increased funding for both the IPF and TELOPS is also required to meet the projected workload.

Software development activities are continuing or will be initiated in support of upcoming space science and applications missions such as Space Telescope, Earth Radiation Budget Satellite, Gamma Ray Observatory, and the Upper Atmosphere Research Satellite which will operate with the Tracking and Data Relay Satellite System. Complex software is required for spacecraft on-orbit and attitude control maneuvers and for the related data processing activities.

## CONSTRUCTION OF FACILITIES, $150,000,000

The Construction of Facilities (CoF) appropriation provides contractual services for the repair, rehabilitation and modification of existing facilities; the construction of new facilities; the acquisition of related facility equipment; the design of facilities projects; and advance planning related to future facilities needs.

The funds requested for 1985 provide for: the continuation of prior year's endeavors in meeting the facilities requirements for the Space Shuttle; Space Shuttle Payload support operations; modification of aeronautical research and development facilities; repair, rehabilitation, and modification of other facilities to maintain, upgrade and improve the usefulness of the NASA physical plant; minor construction of new facilities; and facility planning and design activities.

The projects and amounts in the budget estimate reflect Space Shuttle and Space Shuttle Payload requirements that are time sensitive to meet specific milestones. Other program requirements for 1985 include the repairs to test stand 500 at Marshall Space Flight Center; construction of a numerical aerodynamic simulation facility at the Ames Research Center; modifications to the 8-foot high temperature tunnel at Langley Research Center; construction of an addition to the network control center at Goodard Space Flight Center, construction of an earth and space science laboratory at the Jet Propulsion Laboratory; and construction of a 34-meter antenna, and modifications of a 64-meter antenna, DSS–63, in Spain.

The FY 1985 program continues to meet the objectives of preserving and enhancing the capabilities and usefulness of existing facilities and ensuring safe economical and efficient use of the NASA physical plant. This request continues the necessary rehabilitation and modification program begun in prior years and continues a repair program. The purpose of the repair program is to restore facilities to a condition substantially equivalent to their originally designed capability. The minor construction program continues to provide a means to accomplish smaller facility projects which accommodate changes in technical and institutional requirements.

Funds requested for facility planning and design cover advance planning and design requirements for potential future projects, master planning, facilities studies, engineering reports and studies and the preparation of facility project design drawings and bid specifications.

## CONSTRUCTION OF FACILITIES

### SUMMARY

| Projects | Authorization fiscal year 1985 | Page No. |
|---|---|---|
| 1. Repairs to Test Stand 500 George C. Marshall Space Flight Center | $1,600,000 | 194 |
| 2. Space Shuttle Facilities, at various locations, as follows: | | |
| A. Modification of Site Electrical Substation, Lyndon B. Johnson Space Center | 3,200,000 | 195 |
| B. Modifications for Single Engine Testing, National Space Technology Laboratories | 3,000,000 | 195 |
| C. Construction of Launch Complex 39 Logistics Facility, John F. Kennedy Space Center | 10,000,000 | 196 |
| D. Construction of Solid Rocket Booster Assembly and Refurbishment Facility, John F. Kennedy, Space Center | 15,000,000 | 196 |
| 3. Space Shuttle Payload Facilities, at various locations, as follows: | | |
| A. Construction of Additions to Cargo Hazardous Servicing Facility, John F. Kennedy Space Center | 4,600,000 | 197 |
| B. Construction of Biomedical Research Facility, Ames Research Center | 2,100,000 | 198 |
| 4. Construction of Addition to the Network Control Center, Goddard Space Flight Center | 2,200,000 | 198 |
| 5. Construction of Earth and Space Science Laboratory, Jet Propulsion Laboratory | 12,200,000 | 199 |
| 6. Construction of Numerical Aerodynamic Simulation Facility, Ames Research Center | 11,500,000 | 200 |

SUMMARY—Continued

| Projects | Authorization fiscal year 1985 | Page No. |
|---|---|---|
| 7. Modifications to 8-Foot High Temperature Tunnel, Langley Research Center | 13,800,000 | 200 |
| 8. Construction of 34-Meter Antenna Madrid, Spain (Jet Propulsion Laboratory) | 6,000,000 | 202 |
| 9. Modifications of 64-Meter Antenna, DSS-63, Madrid, Spain (Jet Propulsion Laboratory) | 7,800,000 | 202 |
| 10. Repairs of facilities at various locations, Not In Excess of $750,000 Per Project | 20,000,000 | 203 |
| 11. Rehabilitation and Modification of Facilities at Various Locations, Not In Excess of $750,000 Per Project | 20,000,000 | 204 |
| 12. Minor Construction of New Facilities and Additions to Existing Facilities at Various Locations, Not In Excess of $500,000 Per Project at Various Locations | 5,000,000 | 205 |
| 13. Facility Planning and Design | 12,000,000 | 206 |
| Total, construction of facilities | 150,000,000 | |

1. REPAIRS TO TEST STAND 500 GEORGE C. MARSHALL SPACE FLIGHT CENTER, $1,600,000

This project restores Test Stand 500 to its original test capability to support technology development in $LO_2$ and $LH_2$ engine propulsion. Test Stand 500 was extensively damaged by a hydrogen explosion in late 1980, precluding all hydrogen testing and reducing test rates below subsequent program requirements. Tests and engine operating experience indicate that additional technology development is now required to improve engine performance and reliability, and extend the hours of engine operation.

The hydrogen explosion in 1980 severely damaged the structural members of the test stand and its associated electrical and instrumentation control systems, and high pressure gas lines. The explosion also destroyed a preparation building and technical support building.

The work involves repair of test stand structural members, stairs, and elevator; replacing electrical and instrumentation control systems and high pressure gas lines; and rebuilding the preparation and technical support buildings. The Preparation Support Building, a 28-foot by 48-foot structure, will be a masonry (concret block) construction with electrical and high/low pressure air system provided.

The Terminal Support Building will be a two-story structure, approximately 27 feet and 33 feet, with 16-inch steel reinforced concrete walls.

### 2. SPACE SHUTTLE FACILITIES AT VARIOUS LOCATIONS

#### (A) MODIFICATION OF SITE ELECTRICAL SUBSTATION, LYNDON B. JOHNSON SPACE CENTER $3,200,000

This project provides for the adequate physical separation of the dual 12.47 kV distribution system switchgear, power cables, duct banks, and manholes within the Johnson Space Center (JSC) site substation. This separation is required to eliminate a potential single point failure of the center electrical power system and assure a more reliable electric power service for equipment testing, astronaut training, flight simulations and maintenance of high flight rate support. This project will also replace obsolete fixed-tap transformers with automatic load tap changer transformers to regulate the increasingly frequent out-of-tolerance 12 kV bus voltage.

Although the present electrical system is operationally flexible and nominally redundant, the close proximity of some of the system components threatens the continuity of electrical service under severe electrical faults and/or fire conditions.

Presently, breakers, protective relays, and controls for the Bus 1 and Bus 2 distribution systems are located in the same enclosure. The aisle between the two systems is approximately 6 feet wide. When work or repairs are being performed on one system, the backup system is in jeopardy because of the close proximity and the sensitivity of the controls and protective equipment.

The project will include the purchase and installation of nine 12.47 kV circuit breakers, protective relays, approximately 3,000 feet of power cable duct banks, 13,500 feet of three-phase 15 kV power cable, overhead bus work and associated equipment. This equipment will be located approximately 50 feet west of the existing Bus 1 location and will replace the present Bus 1 equipment. In addition, the two fixed-tap main site transformers will be replaced with two 25 MVA transformers with automatic load-tap changers, control wiring and foundations.

#### (B) MODIFICATIONS FOR SINGLE ENGINE TESTING, NATIONAL SPACE TECHNOLOGY LABORATORIES, $3,000,000

This project provides for modifications to the Main Propulsion Test (MPT) Stand at the National Space Technology Laboratories (NSTL) to provide capability for single Space Shuttle Main Engine (SSME) testing. The testing is necessary for engine improvements leading to life extension of key engine components at greater reliability. The current capability to conduct three-engine cluster firings in the modified test stand will also be retained.

A key aspect of this objective is to improve the performance of the SSME at full power and to extend the life of the engine.

To support the heavy work load of turbo-machinery, engine improvements and life-cycle testing a third test position will be required in 1986. This project provides the necessary modifications of

the B-2 position of the MPT Stand for Single Engine Testing to meet these test requirements.

The project modifications include: removal of the Shuttle external tank and installation of existing liquid oxygen/liquid hydrogen run tanks; modification of the stand structure to support the installation of the run tanks and servicing of the engine; modification of the propellant fill and drain lines; rerouting existing high-pressure gas lines to accommodate the new configuration; and minor instrumentation changes. A new single engine mount will also be provided.

The propellant feed lines will be modified for interconnection to the liquid hydrogen and liquid oxygen barges, docked nearby, which provide propellant replenishing capability. The facility modifications will be engineered to facilitate removal of the run tanks for return to the external tank MPTA configuration to support three-engine cluster firing.

### (C) CONSTRUCTION OF LAUNCH COMPLEX 39 LOGISTICS FACILITY, JOHN F. KENNEDY SPACE CENTER, $10,000,000

This project continues work partially funded in FY 1984 for construction of a logistics facility in the Kennedy Space Center (KSC) Launch Complex 39 (LC-39) area. It will provide critically needed storage space to support Space Shuttle processing, checkout and launch operations. This increment of funding will complete an approximately 265,000-square foot logistics facility, a petroleum oil and lubricants (POL) storage area, and associated loading docks, truck ramps, parking, access roads, and railroad spur.

The increasing orbiter fleet and flight rate have added to the complexity of the logistics and warehousing functions at KSC.

Currently, items are being stored in KSC institutional logistics facilities and other scattered facilities. The present storage facilities are inefficient and geographically poorly situated. A more efficient overall logistics configuration is needed for the operations of the Shuttle Processing Contractor (SPC). This facility is urgently required for the SPC to efficiently support increasing flight rates and to adequately protect the government's investment in Shuttle parts and support equipment.

This budget request is for the second increment of funding for construction of an approximately 265,000-square foot logistics facility south of the Vehicle Assembly Building (VAB). The facility will be designed to provide 200,000 square feet of storage including shelf storage, pallet and rack storage, automated storage, conditioned storage and secure storage; 25,000 square feet for receiving and shipping; and 40,000 square feet of support areas.

The project also includes a POL storage/holding area, loading docks and truck ramps, parking for vehicles, necessary road intersection modifications, and a rail spur extending from the existing rail line, west of Contractor Road.

### (D) CONSTRUCTION OF SOLID ROCKET BOOSTER ASSEMBLY AND REFURBISHMENT FACILITY, $15,000,000

This project continues work funded in prior years for the construction of an SRB Assembly and Refurbishment Facility at Ken-

nedy Space Center. It will provide a consolidated facility which is specifically designed for production flow layout and configuration for efficient processing of the Solid Rocket Booster propulsion system components that are required to support the Space Transportation System (STS) mission model.

As a result of detailed studies by NASA, industry teams, and industrial consultants, the existing VAB low bay SRB processing facilities were found to be inefficient, costly to operate, and unable to satisfy flight rate schedules beyond approximately 16 per year. This new facility will provide a consolidated and specifically designed production flow layout to promote efficiency in flight hardware processing and meet the planned flight rates. Only the Hangar AF Complex which includes the SRB disassembly facilities, the TVC deservicing/disassembly, and Bostic Paint facility will be retained.

The SRB Assembly and Refurbishment Facility will be designed by the selected SRB processing contractor. The facility will include manufacturing and administrative areas; paint, oil and lubricants (POL) storage for volatile and flammable liquids; and a hazardous waste building for temporary staging of hazardous waste prior to removal from the site. The manufacturing building will provide work areas, spray cells, and cure cells for required special castings. A clean environment will be provided for forward and aft assemblies and subassemblies. Ordnance shop facilities, supply storage, and other process facilities will also be provided. The project also includes the provision of a safe area for conducting TVC hot firings.

### 3. SPACE SHUTTLE PAYLOAD FACILITIES, AT VARIOUS LOCATIONS

#### (A) CONSTRUCTION OF ADDITIONS TO CARGO HAZARDOUS SERVICING FACILITY, JOHN F. KENNEDY SPACE CENTER, $4,600,000

This project provides additional capabilities for processing large hazardous cargo in support of the Space Transportation System (STS). The existing facility provides the capability to safely load propellants and explosive ordnance for vertical payloads of the maximum size planned for flight on the STS Orbiters. This project will add an airlock, construct a concrete pad in front of the airlock, provide additional site preparation work, and construct a control building. These additions will allow the payload processing throughout to be increased from the present four payloads per year to eight.

This project will complete the Cargo Hazardous Servicing Facility. With this project, an airlock will be provided to preserve the stringent contamination control integrity of the service bay during entrance/exit of a payload. The planned control building will provide an engineering support facility, equipment rooms, SCAPE suit changeout, and payload control rooms. This control building will permit the set up of the communications and control equipment at a safe distance from the servicing cell. After the hazardous processing is completed, unrestricted use of this equipment can be continued for maintaining payload communications and configuration control through launch.

This project provides for construction of a 90-foot high bay entrance airlock of approximately 4,000 square feet, and the construction of a single-story control building enclosing approximately 9,500 square feet with two payload control rooms and supporting engineering and shop space. The airlock will provide a class 100,000 clean room atmosphere for cargo operations. A door approximately 35 feet wide by 75 feet high will be provided to accommodate the cargo canister in a vertical position on its transporter. Also provided in this project is a 35-foot high steel frame payload transporter shed covering 6,600 square feet, and two 16-foot high steel frame tanker sheds, each covering approximately 1,000 square feet.

### (B) CONSTRUCTION OF BIOMEDICAL RESEARCH FACILITY, AMES RESEARCH CENTER, $2,100,000

Ames Research Center (ARC) has been designated as the NASA lead center for all animal experiments for the Space Lab Program. In addition to this specific life science effort, ARC conducts aerospace experimentation and research over a broad spectrum of biomedical disciplines. Current laboratory and support facilities associated with the ARC Animal Care Facility (ACF) are a makeshift collection of aging trailers that are expensive to maintain, unsightly, and substandard for animal care and occupational safety.

Construction of an adequate facility to replace the trailer complex will save high maintenance and repair costs as well as provide necessary flexible and efficient capability to meet vital requirements of the Life Sciences Program.

This project provides for the construction of approximately 21,000 square feet of laboratory and support facilities to replace 18 obsolete trailers and 1 environmental chamber. The facility will include 6,700 square feet of support facility space and 10,500 feet of research laboratory and office space. The proposed building will be located south of and adjacent to the existing ACF where the substandard trailers are now located.

### 4. CONSTRUCTION OF ADDITION TO THE NETWORK CONTROL CENTER, GODDARD SPACE FLIGHT CENTER, $2,200,000

This project provides for the construction of a two-story 32,000-square foot addition to the Network Control Center (NCC) required for the Tracking and Data Relay Satellite System (TDRSS). This addition is necessary to provide essential equipment and work space for technical and support functions for NASA and the Department of Defense (DOD). The NCC is the computer based scheduling and control interface between the user community and the TDRSS. Operational support equipment and related NCC activities require additional space and upgrading of the building utility systems. Because DOD security requirements are embedded in the overall NCC operations, the NCC must conform to DOD security standards.

The project is sponsored jointly by NASA and the United States Air Force (USAF) at a total estimated costs of $5,700,000.

Title to this facility addition will be vested with NASA (GSFC).

The NCC at GSFC is a critical element in TDRSS operations, providing 24 hours per day, 7 days per week scheduling for individ-

ual spacecraft support and on-line control of the TDRSS to meet user requirements.

Developments of the NCC from inception to the current configuration now needed for full and secure TDRSS operations has led to requirements for additional facility space. The necessary equipment has overcrowded the present facility and exceeded the electrical power and air conditioning capability.

This project will provide for the construction of a 32,000-square foot, two-story addition to Building 13. The addition will be of brick contruction with a structural steel frame supported on a drilled caisson foundation system.

### 5. CONSTRUCTION OF EARTH AND SPACE SCIENCE LABORATORY, JET PROPULSION LABORATORY, $12,200,000

This project provides for the construction of an Earth and Space Science Laboratory at the Jet Propulsion Laboratory (JPL). This facility is required to house equipment and activities of 295 scientific, engineering and other personnel working on rapidly expanding radar, oceans, and electronic component development and test programs. The building will be a two-story structure of approximately 90,000 square feet composed of laboratory, computer, test, and associated technical support space. It will provide facilities to accommodate imminent program expansions and required improved conditions for the development, testing and evaluation of unique spacecraft component systems.

JPL is assigned responsibility for NASA deep space scientific exploration, tracking and data acquisition, and the development of spacecraft.

Successful accomplishment of radar and ocean program activities involves an increase in personnel from 128 to about 230 by 1986 with a budget increase in excess of $50.0 million. In addition, $3.0 million of instruments and test systems to support the demanding test and analysis requirements of VRM, SIR and future spacecraft systems are being acquired. This equipment requires stringent temperature and humidity controlled environment, clean rooms, and electrostatic protection for effective operation.

The existing space is over-crowded and cannot be economically expanded to accommodate the necessary test and data analysis equipment that is being acquired, and it cannot be modified for adequate clean room environment and temperature and humidity control. Colocation of radar, oceans, and electronic component development personnel will facilitate information exchange, eliminate duplication of facilities, and reduce administrative costs.

Site conditions at JPL are such that a two-story laboratory of this size with computers and test equipment on the first level and supporting functions on the second level is the most cost effective design for satisfying the requirement.

The building will be of steel frame construction with a metal roof deck and a reinforced concrete slab on grade. The laboratories will be provided with precise temperature and humidity controls. Two high bay laboratories and the mechanical and electrical equipment rooms are also included. Special systems include appropriate shielding, approximately 20,000 square feet of computer flooring,

necessary electronic grounding, and heat exhaust systems for the computer equipment.

### 6. CONSTRUCTION OF NUMERICAL AERODYNAMIC SIMULATION FACILITY, AMES RESEARCH CENTER, $11,500,000

The Numerical Aerodynamic Simulation (NAS) program is an integral element of NASA's aerodynamic research and development capability. The NAS activity will provide and maintain a leading computational capability for NASA, other Government agencies, industry, and universities. The NAS processing system network will offer an advanced high-speed computational capability for aerodynamic research, aeroelastic simulation, solving viscous 3-D fluid flow equations and advance fluid physics research. This project provides the facility to house the computational system, support areas, and space for operations, development, resident research, and maintenance staff. Space will also be provided for the system development staff, who will be available for necessary upgrading of the NAS Processing System Network (NPSN).

As an element of NASA's Numerical Aerodynamic Simulation Program, this system will provide a simulation capability to support advanced fluid dynamic and aerodynamic research, development, test, and evaluation. Advanced design objectives of future aircraft, such as negative static stability and automatic aerodynamic tailoring, require very high speed computation of great compexity and very large data capacity. This capability does not exist in NASA. For mathematical modeling of aircraft of the future, the described computational capability must be available. The system will also support the solution to other complex problems of interest to NASA, including such fields as meteorology, climate research, structural analysis, and computational chemistry.

The computer equipment will demand unique power and cooling requirements. Adequate facilities must be provided for this advanced, high-speed computer system. In addition, the computer system must be housed in a secure environment.

The project provides a 90,500 square foot, two-story building to house the NAS Processing System Network, associated peripheral equipment, and secure computer equipment. Special power conditioning, emergency power, utilities management, and process cooling will be installed.

The necessary physical security and fire protection systems will also be provided.

The remainder of the building will house mechancial equipment, storage, utilities, corridors, rest rooms, and similar space. The project also includes site development, access roadway, parking, utilities, and site landscaping.

### 7. MODIFICATIONS TO 8-FOOT HIGH TEMPERATURE TUNNEL, LANGLEY RESEARCH CENTER, $13,800,000

This project will support significant advances in supersonic and hypersonic research by adding new capability to the 8-Foot High Temperature Tunnel in Building 1265 and upgrading existing support systems and equipment. These modifications will provide aerothermodynamic and structural testing capability for air-breathing propulsion systems for aircraft and missiles which operate at alti-

tudes from 50,000 feet to 120,000 feet and Mach numbers between 4.0 and 5.0. Research capability for testing hydrogen and hydrocarbon-fueled ramjets and scramjets will also be provided by these facility modifications.

The Langley Research Center (LaRC) has been developing a technology base for hydrogen and hydrocarbon scramjets and has conducted limited evaluations on subscale engines. Present advances are focused on an airframe integrated concept that includes a vehicle forebody/inlet, combustor and vehicle/afterbody nozzle. However, existing small scale facilities severely limit testing capabilities. To advance this technology, full-scale tests are required to demonstrate a complete flight-weight, flight-scale engine system to determine engine performance, module interactions, nozzle thrust effects and engine scale performance. Full-scale structural test capability is also required to determine engine component interactions, cooling performance, and thermal structural performance.

Current facilities can accommodate full-scale ramjets and missile models up to about Mach 4. Other test facilities can simulate flight Mach numbers up to Mach 7, but they are small and can only accommodate limited subscale engine development. The Langley 8-Foot High Temperature Tunnel currently has the capability for aerothermodynamic and thermal structural testing from Mach 5.8 to Mach 7.2, but has no propulsion testing capability and also leaves a gap in the Mach 4–5 range. It is the only facility in the country that can be cost-effectively modified to fill this gap to support propulsion testing and full scale missile research.

In addition to NASA, the Department of Defense (DOD) has ongoing ramjet/scramjet and missile development programs which could be tested in the modified tunnel. A complete missile tested at conditions simulating the entire altitude/Mach number envelope of flight would greatly reduce development risk, time, and cost.

Current research is limited by the nonavailability of a facility capable of providing a high mach number (4–5) and large scale testing.

In order to provide increased capability, this project provides for modifications in three areas: (1) the replacement and overhaul of several high use pieces of tunnel support equipment; (2) the addition of an oxygen-enrichment system which will allow the test stream to simulate air for propulsion testing; and (3) new nozzles to provide for facility testing capability in the Mach 4 to 5 range.

The required facility modifications include rehabilitating the methane gas and gaseous hydrogen systems, replacing compressor systems, modifications to the piping system, new combustion air control values, etc. In addition, the cooling system for the model support strut will also be modified.

An oxygen enrichment system will be provided to replenish the oxygen depleted in burning methane and air to provide the true environment required for hypersonic flow simulation. This system will inject oxygen directly into the annular space between the inner and outer liners of the combustor. Oxygen will be supplied from an isolated liquid oxygen run tank. This includes a nitrogen system for evacuating oxygen when the facility is not in operation, and additional supply lines and storage tanks.

Alternate Mach number capability will be provided to extend the operating characteristics of the tunnel.

**8. CONSTRUCTION OF 34-METER ANTENNA MADRID, SPAIN (JET PROPULSION LABORATORY), $6,000,000**

This project provides for the construction of a 34-meter diameter X-band frequency antenna at the Deep Space Network (DSN) complex in Madrid, Spain. The antenna is necessary for meeting Voyager 2-Neptune encounter communication requirements, supporting Galileo science experiments and navigation requirements, and reducing the communications overload at the Madrid complex to minimize science data losses. This antenna will be combined in an array with the other DSN antennae at the complex for large aperture requirements, and used separately to provide the improved capability needed for concurrent support of miltiple spacecraft from Madrid.

This new antenna must be operational by mid-1987 to support the Galileo mission. It will be used to support gravity wave experiments in late 1987 and late 1988, and for critical backup VLBI (very long baseline interferometry) navigation for the Galileo probe beginning March 1988. In addition, this antenna is needed for improving multiple mission support capability to achieve communications requirements in the later 1980's and beyond.

This network balance will improve the overall DSN support uniformity for fuller realization of the scientific potential of current and future missions.

This project provides for the construction of a 34-meter diameter X-band frequency antenna at the Madrid complex in Spain. Site support facilities include an entrance road, security fencing, grading, paving, drainage, electrical power distribution, and fire protection. The antenna will be installed on a new foundation and furnished with the necessary control system. The antenna includes all structural, mechanical, and electrical elements; reflector surface panels; the subreflector; and a support systems enclosure.

**9. MODIFICATIONS OF 64-METER ANTENNA, DSS–63, MADRID, SPAIN (JET PROPULSION LABORATORY), $7,800,000**

This project provides modifications for upgrading the 64-meter DSS–63 antenna at the Deep Space Network (DSN) Complex in Madrid, Spain, to a 70-meter diameter, higher efficiency antenna. The upgrading improves by 45 percent the communication capability to provide required support for deep space missions. This project is necessary for support of the Galileo, Venus Radar Mapper, and Voyager 2—Neptune missions, for continuing support to spacecraft beyond the outer planets, and for improving various deep space scientific data gathering capabilities.

Upgrading this antenna to a 70-meter diameter and incorporating today's technology to improve efficiency will extend the communication threshold and coverage for the Pioneer 10, Voyager 1, and Voyager 2 spacecraft by up to five years as they depart the solar system in the 1990's. The modifications will provide needed improvements in this antenna's capability for very long baseline interferometry (VLBI), radio science, radio astronomy, emergency spacecraft command transmitting, and spacecraft data telemetry.

Similar modifications are planned for the 64-meter antenna at Goldstone, California, and the one at Canberra, Australia.

This project, and future projects for the other two DSN 64-meter antennae, will incorporate this new technology.

This antenna in Spain must be modified in FY 1985 so it may be returned to operation in time for Galileo support in 1987. This is also necessary for enabling the future sequential modification of the 64-meter antennae at Goldstone and Australia in time to support the Voyager 2—Neptune encounter without removing more than one antenna at a time from spacecraft support.

The modifications will incorporate state-of-the-art technology for antenna component design, fabrication, and alignment. High efficiency X-band panels will be installed over the full reflector surface. The reflector backup structure will be enlarged to a 70-meter diameter and modified for increased strength and stiffness. A new quadripod and high precision subreflector compatible with the 70-meter reflector will be installed. The elevation wheel will be reinforced for strength and stiffness and increased in weight to balance the modified reflector-subreflector assembly. A new drive and control system for the new subreflector is also included.

**10. REPAIRS OF FACILITIES AT VARIOUS LOCATIONS, NOT IN EXCESS OF $750,000 PER PROJECT, $20,000,000**

These resources will provide for large repairs to facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. Included in the request are those facility repair needs for FY 1985 that can be foreseen at the time of the submission of these estimates, and that are estimated not to exceed $750,000 per project. The thrust of this program is to provide a means to restore facilities of components thereof, including collateral equipment, to a condition substantially equivalent to their originally intended and designed capability. The request includes the substantially equivalent replacement of utility systems and collateral equipment necessitated by incipient or actual breakdown. This work also includes major preventive measures which are normally accomplished on a cyclical schedule of greater than one year.

A major portion of the Agency's buildings exceed 15 years in age, and increases in repair requirements are to be expected. Maintenance and repair costs for mechanical and electrical systems in a typical building are almost three times higher during the 16- to 30-year period of a building's life than they are during the initial 15 years of beneficial occupancy. At about the 15-year point, many electrical and mechanical components reach the end of their serviceable or economic life and should be replaced in the interest of long-term economy. Continued piecemeal repair of these components usually requires more resources in the long run than replacement after the end of the economic life of the original components. Some 75 percent of the physical plant is in the 16- to 30-year old category.

The major thrust of this repair program, as well as the rehabilitation and modification program, is to preserve the Agency's $3.3 billion (as of September 30, 1983) physical plant. The major distinction between these classes of work is whether or not the intended

work is to bring the facility and its components to a condition substantially equivalent to its designed capacity, efficiency, and capabilities. If such is the case, the work is classified as repair. An analysis of each of the projects for which funds are requested indicates that this work must be addressed and progressively accomplished. Otherwise, risks are increased and future costs of the specific work will be greater. More importantly, there will be increased breakdowns that require costly emergency repairs.

This program includes only facility repair work having an estimated cost not in excess of $750,000 per project. The work is of such a nature and magnitude that it cannot be accomplished by routine day-to-day facility maintenance and repair activities, or by related routine facility work efforts that are provided for in other than CoF estimates.

Based on relative urgency and expected return on investment, the projects which comprise this request are of the highest priority. Deferral of this mission-essential work would adversely impact the availability of critical facilities and program schedules.

| Summary of project amounts by location: | *Amount* |
|---|---|
| Ames Research Center | $1,395,000 |
| Dryden Flight Research Facility | 195,000 |
| Goddard Space Flight Center | 1,180,000 |
| Jet Propulsion Laboratory | 1,900,000 |
| Johnson Space Center | 1,225,000 |
| Kennedy Space Center | 1,455,000 |
| Langley Research Center | 2,625,000 |
| Lewis Research Center | 2,440,000 |
| Marshall Space Flight Center | 955,000 |
| Michoud Assembly Facility | 1,665,000 |
| National Space Technology Laboratories | 2,425,000 |
| Wallops Flight Facility | 1,555,000 |
| Various locations | 690,000 |
| Miscellaneous projects not exceeding $150,000 each | 295,000 |
| Total | 20,000,000 |

**11. REHABILITATION AND MODIFICATION OF FACILITIES AT VARIOUS LOCATIONS, NOT IN EXCESS OF $750,000 PER PROJECT, $20,000,000**

These resources will provide for the rehabilitation and modification of facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. Included in this request are those facility rehabilitation and modification needs for FY 1985 that have been fully identified at the time of the submission of these estimates, and that are estimated not to exceed $750,000 per project. The purpose of this program is to restore or enhance the condition of a facility so that it can more effectively accomplish its designated purpose or increase its functional capability.

Based on the initial investment costs, the NASA Capital Type Property totals approximately $8.0 billion (September 30, 1983), of which the physical plant comprises some $3.3 billion. A continuing program of rehabilitation and modification of these facilities is required to:

(a) Protect the capital investment by minimizing the cumulative effects of wear and deterioration;

(b) Ensure that these facilities are continuously available and that they operate at peak efficiency;

(c) Improve the capabilities and usefulness of these facilities and thereby mitigate the effects of obsolescence;

(d) Provide a better and safer environment for all personnel; and

(e) Provide significant reductions in energy consumption through the initiation of energy conservation projects including improved utility control systems.

This program includes only facility rehabilitation and modification work having an estimated cost not in excess of $750,000. The work is of such a nature and magnitude that it cannot be accomplished by routine day-to-day facility maintenance or by related routine facility work efforts that are provided for in other than CoF estimates.

| Summary of project amounts by location: | *Amount* |
|---|---|
| Ames Research Center | $1,985,000 |
| Dryden Flight Research Facility | 360,000 |
| Goddard Space Flight Center | 1,180,000 |
| Jet Propulsion Laboratory | 2,105,000 |
| Johnson Space Center | 2,255,000 |
| Kennedy Space Center | 2,070,000 |
| Langley Research Center | 2,895,000 |
| Lewis Research Center | 2,800,000 |
| Marshall Space Flight Center | 2,730,000 |
| Michoud Assembly Facility | 1,850,000 |
| National Space Technology Laboratories | 960,000 |
| Wallops Flight Facility | 2,615,000 |
| Various locations | 750,000 |
| Miscellaneous projects not exceeding $150,000 each | 445,000 |
| *General reduction* | *−5,000,000* |
| Total | 20,000,000 |

**12. MINOR CONSTRUCTION OF NEW FACILITIES AND ADDITIONS TO EXISTING FACILITIES AT VARIOUS LOCATIONS, NOT IN EXCESS OF $500,000 PER PROJECT AT VARIOUS LOCATIONS, $5,000,000**

These resources will provide for minor facility construction at NASA field installations and Government-owned industrial plants supporting NASA activities. Each project included in this program is estimated to cost not more than $500,000 and involves either the construction of new facilities or additions to facilities. The FY 1985 request of $5,000,000 will improve the usefulness of NASA's physical plant by changing the utilization of or augmenting the capabilities of various facilities. Included in this request are those programmatic and institutional projects that are essential to the accomplishment of mission objectives.

The configuration of NASA's physical plant necessarily must respond to changes in utilization and adaptations required by changes in technology or in mission needs. Demands are generated by research, development, test, and similar activities.

| Summary of project amounts by location: | *Amount* |
|---|---|
| Ames Research Center | $490,000 |
| Dryden Flight Research Facility | 200,000 |
| Jet Propulsion Laboratory | 610,000 |
| Kennedy Space Center | 1,145,000 |
| Langley Research Center | 655,000 |
| Lewis Research Center | 460,000 |
| Marshall Space Flight Center | 240,000 |
| National Space Technology Laboratories | 245,000 |
| Wallops Flight Facility | 670,000 |
| Various locations | 285,000 |
| Total | 5,000,000 |

**13. FACILITY PLANNING AND DESIGN, $12,000,000**

The funds requested in this estimate are required to provide for the following advance planning and design activities related to facilities activities and projects:

(a) The accomplishment of necessary development and master planning for field installations and, where not otherwise provided for, the provision of continuing engineering support and special engineering management and other services.

(b) The preparation of preliminary engineering reports, cost estimates, and design and construction schedules.

(c) The preparation of final construction plans, specifications, and associated cost estimates and schedules required to implement construction projects.

(d) The accomplishment of facilities siting and other investigations, studies and reports.

Regular requirements encompass the basic purposes outlined above. The "other requirements," while also in support of "regular" purposes, cover those special needs related to large, complex projects or specific programs considered to represent high potential future construction requirements and for which early definition is essential. The large projects require more planning and longer lead time. Much of this planning must be completed prior to inclusion of the project in a budget request.

| | *Amount* |
|---|---|
| Regular requirements | ($7,150,000) |
| Master planning | 200,000 |
| Sustaining engineering support | 550,000 |
| Preliminary engineering reports and related special engineering support | 2,350,000 |
| Final design | 4,050,000 |
| Other requirements | (4,850,000) |
| Space shuttle facility planning and design | 1,050,000 |
| Payload facility planning and design | 1,150,000 |
| Altitude wind tunnel | 2,650,000 |
| Total | 12,000,000 |

## RESEARCH AND PROGRAM MANAGEMENT, $1,331,000,000

SUMMARY OF BUDGET PLAN BY FUNCTION

| | |
|---|---|
| Personnel and related costs | $935,928,000 |
| Travel | 28,000,000 |
| Operation of installation | 367,072,000 |
| Total | 1,331,000,000 |

The Research and Program Management appropriation funds the performance and management of research, technology and test activities at NASA installations, and the planning, management and support of the many and varied contractor research and development tasks necessary to meet the Nation's ongoing objectives in aeronautical and space research. Objectives of the efforts funded by the Research and Program Management appropriation are to (1) provide the technical and management capability of the civil service staff needed to conduct the full range of programs for which NASA is responsible, (2) provide base maintenance of facilities and manage their use in support of research and development programs, and (3) provide effective and efficient technical and administrative support for the research and development programs. For 1985, an appropriation of $1,331,000,000 is requested.

The 22,000 permanent and temporary civil service personnel at eight major installations and Headquarters are funded by the Research and Program Management appropriation. This civil service workforce is NASA's most important resource and is vital to future space and aeronautics research activities. Seventy percent of the Research and Program Management appropriation is needed to provide for salaries and related costs of this civil service workforce. About two percent is for travel, critical to manage successfully the Agency's in-house and contracted programs. The remaining amount of the Research and Program Management appropriation provides for the research, test and operational facility support, and for related goods and services necessary to operate the NASA installations and to accomplish NASA's approved missions efficiently and effectively.

NASA field centers report to the Program Associate Administrator responsible for the major portion of their technical programs. The principal roles assigned each installation based on demonstrated capabilities and capacities to meet NASA's overall program goals are as follows:

*Office of Space Flight*

*Johnson Space Center.*—Manage the integrated Space Shuttle program including Orbiter production and operation; astronaut and mission specialist selection and training; STS Operations including mission planning, operational procedures and flight control; and

application of remote sensing to agricultural assessments and other Earth resources uses.

*Kennedy Space Center.*—Launch of Space Shuttle flights; the ground operational phase of the Space Transportation System; and the preparation and launch of payloads on the Space Shuttle and expendable launch vehicles.

*Marshall Space Flight Center.*—Manage the Space Shuttle main engine, solid rocket booster and external tank projects; management of NASA's activities on the Spacelab project; management of large automated spacecraft projects such as the Space Telescope; and experiments in materials processing in space.

*National Space Technology Laboratories.*—Support Space Shuttle engine procurement and testing; regional Earth resources research and technology transfer; and support functions for other Government agencies located there.

*Office of Space Science and Applications*

*Goddard Space Flight Center.*—Develop and operate the Earth orbital flight experiments and automated spacecraft to conduct scientific investigations and demonstrate practical applications; the management of the tracking and data acquisition activities for Earth orbital missions; management of the Delta launch vehicle program; management and launch of sounding rockets and balloons; and operation of an instrumented flight range for aeronautical and space research. The Wallops Facility is an operational element and component installation of the Goddard Space Flight Center.

*Office of Aeronautics and Space Technology*

*Ames Research Center.*—Develop short haul aircraft and rotorcraft research and technology, computational fluid dynamics, planetary probe research, life sciences, aeronautical flight research and testing, as well as providing an alternate landing site for Space Shuttle operational missions at the Dryden Flight Research Facility, an operational element and component installation of Ames.

*Langley Research Center.*—Develop long haul aircraft research and technology, emphasizing fuel conservation, safety and environmental effects; aerospace structures technology; environmental quality monitoring by remote sensing; and advanced space systems technology.

*Lewis Research Center.*—Develop and maintain aeronautical and space propulsion research and technology; space communications research and technology; space energy systems research and technology; and development of the Centaur cryogenic upper stage for use in the Space Shuttle and management of the Centaur expendable launch vehicle program.

The 1985 budget provides the necessary resources to apply these in-house capabilities to program activities. Detailed data on funding requirements are provided in the section on each installation. A summary description of, and the funding required by functional category, include:

## PERSONNEL AND RELATED COSTS, $935,928,000

### COMPENSATION AND BENEFITS

*1. Compensation*

*a. Permanent positions.*—This part of Personnel and Related Costs covers the salaries of the full-time permanent civil service workforce and is the largest part of this functional category.

*b. Other than full-time permanent positions.*—This category includes the salaries of NASA's non-permanent workforce. Programs such as students participating in cooperative training, summer employment, youth opportunity, and temporary clerical support are covered in this category.

*c. Reimbursable detailees.*—In accordance with existing agreements, NASA reimburses the parent Federal organization for the salaries and related costs of persons detailed to NASA.

*d. Overtime and other compensation.*—Overtime, holiday, post and night differential, and hazardous duty pay are included in this category. Also included are incentive awards for outstanding achievement and superior performance awards.

*2. Benefits*

In addition to compensation, NASA makes the employer's contribution to personnel benefits as authorized and required by law. These benefits include contributions to the Civil Service Retirement Fund, employees' life and health insurance, payments to the Medicare fund for permanent employees, and social security contributions for non-permanent personnel. Payments to the civil service retirement fund for re-employed annuitants and for severance pay to former employees involuntarily separated through no fault of their own are also included.

### SUPPORTING COSTS

*1. Transfer of personnel.*—Relocation costs, such as the expenses of selling and buying a home, and the movement and storage of household goods are provided under this category.

*2. Office of Personnel Management Services.*—The Office of Personnel Management is reimbursed for certain activities such as security investigations on new hires, recruitment advertising, and career-maturity surveys.

*3. Personnel training.*—Training is provided within the framework of the Government Employees Training Act of 1958. Part of the training costs consists of courses offered by other Government agencies, and the remainder provides for training through non-government sources.

## TRAVEL, $28,000,000

*Program travel*

The largest part of travel is for direction, coordination and management of program activities including international programs and activities. The complexity of the programs and the geographical distribution of NASA installations and contractors necessitate the need for this category of travel. As projects reach the flight

stage, support is required for prelaunch activities, including overseas travel to launch and tracking sites. The amount of travel required for flight projects is significant as it is directly related to the number of systems and subsystems, the number of design reviews, and the number and complexity of the launches and associated ground operations.

*Scientific and technical development travel*

Travel to scientific and technical meetings and seminars permits employees engaged in research and development to participate at both Government-sponsored and nongovernment-sponsored seminars. This participation allows personnel to benefit from exposure to technological advances which arise outside NASA, as well as allowing personnel to present both accomplishments and problems to their associates and provides for the dissemination of technical results to the U.S. community. Many of the Government-sponsored meetings are working panels convened to solve certain problems for the benefit of the Government.

*Management and operations travel*

Management and operations travel provides for the direction and coordination of general management matters and travel by officials to review the status of programs. It includes travel by functional managers in such areas as personnel, financial management and procurement. This category also includes the cost of travel in and around the Installations; travel of unpaid members of research advisory committees; and initial duty station, permanent change of assignment, and other family travel expenses. Payments to interagency motor pools are included in the Operation of Installation function (Management and Operations subfunction).

## Operation of Installation, $367,072,000

FISCAL YEAR 1985 BUDGET PLAN

| | |
|---|---|
| Facilities services | $198,679,000 |
| Technical services | 57,765,000 |
| Management and operations | 110,628,000 |
| Total | 367,072,000 |

Operation of Installation provides a broad range of services, supplies, and equipment in support of the centers' institutional activities. These are divided into three major subfunctional areas: Facilities Services (the cost of renting real property, maintaining and repairing institutional facilities and equipment, and the cost of custodial services and utilities); Technical Services (the cost of automatic data processing for management activities, and the cost of educational and information programs and technical shops supporting institutional activities); and Management and Operations (the cost of administrative communications, printing, transportation, medical, supply, and related services). A description of each major subfunction follows:

*Facilities Services*

*1. Rental of real property.*—Rental of real property includes the rental of building space directly by NASA or through the General Services Administration to meet offsite office, warehousing, and other requirements which cannot otherwise be provided in existing buildings at the NASA Installation. Most of the funding is required for rental of the NASA Headquarters complex of buildings in the District of Columbia, and nearby Maryland and Virginia that are either Government-owned or leased for which NASA must provide rental payments to the General Services Administration in accordance with P.L. 92-313. Also included in this item is rental of trailers required to accommodate special short-term needs.

*2. Maintenance and related activities.*—Maintenance and related activities include the recurring day-to-day maintenance of facilities (ground, buildings, structures, etc.) and equipment which is accomplished by non-Civil Service personnel. This involves the mowing and care of grassy areas, care of trees and shrubs, elevators, cranes, pressure vessel inspections, painting and protective coatings, general buildings maintenance, and the maintenance of installed mechanical, electrical, and other systems. In addition, this item includes feasibility studies, project design, construction supervision, inspection, and other institutional facility engineering functions. Included also are any applicable costs associated with recurring facility work as well as materials, hardware, and equipment used in facility maintenance activities, whether accomplished by civil service personnel or contractors. In the cost of equipment, related maintenance and other services are reflected for office, shop, laboratory and other facilities equipment as well as administrative internal communications and television monitoring equipment.

*3. Custodial services.*—Custodial services include janitorial and building cleaning services, pest control, fire protection services, security services including badging and identification, lock and safe repair, trash and refuse handling, window blinds and light fixture cleaning, and laundry and dry cleaning of facility related items.

*4. Utilities services.*—Utilities services include the purchase of utilities such as electricity, natural gas, fuel oil, coal, steam, propane, and other fuel commodities as well as water and sewage treatment services. Also included are the related maintenance and operating costs of the utility plants and systems.

*Technical services*

*1. Automatic data processing*

*a. Equipment.*—This category provides for the lease, purchase and maintenance of general purpose data processing equipment which supports institutional operations at each installation. Excluded is equipment dedicated to specific research or operational systems which is funded from the Research and Development appropriations.

*b. Operations.*—Operations services include programming, computer operations and related services for institutional applications including payroll, financial management, security, maintenance, personnel, logistics, and procurement records and reports.

*2. Scientific and technical information and educational programs*

*a Libraries.*—The technical libraries are established to provide installation staffs with books, periodicals, technical reports and other scientific documentation.

*b. Education and information programs.*—The educational and informational programs provide for the documentation and dissemination of information about the Agency's programs to the general public, the educational community at the elementary and secondary levels, and the mass communications media. Assistance to the mass communications media includes the assembly and exposition of newsworthy material in support of requests in the form of press kits, news releases, television and radio information tapes and clips, and feature material.

*c. Shop and support services.*—Shop and support services include general fabrication shops, reliability and quality assurance activities, safety, photographic services, graphics, and audio-visual material.

*Management and operations*

*1. Administration communications.*—Included in this category are costs of leased lines not dedicated to a specific program or project, long distance tolls (including FTS charges), teletype services, and local telephone service.

*2. Printing and reproduction.*—Included in this category are the costs for duplicationg, blueprinting, microfilming, and other photographic reproductions. Also included in this category are Government Printing Ofice printing costs, contractual printing and the related composition and binding operations.

*3. Transportation.*—Transportation services include the operation and maintenance of all general purpose motor vehicles used by both civil service and support contrator personnel. The cost of movement of supplies and equpment by commercial carriers and payments to interagency motor pools are also in this category.

*4. Installation common services.*—Installation common services include support activities at each installation such as: occupational medicine and environmental health; mail service; supply management; patent services; administrative equipment; office supplies and materials; and postage.

## FISCAL YEAR 1985 NASA CIVIL SERVICE EMPLOYEE DISTRIBUTION

| | Johnson | Kennedy | Marshall | NSTL | Goddard | Ames | Langley | Lewis | Hq. | Total | JPL[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RESEARCH AND DEVELOPMENT | 1,097 | 530 | 2,208 | 46 | 2,159 | 1,461 | 2,147 | 1,950 | 390 | 11,988 | 1,587 |
| Space station | 200 | 100 | 150 | ..... | 50 | 25 | 25 | 25 | 25 | 600 | ..... |
| Space transportation capability development | 653 | 297 | 726 | 5 | ..... | ..... | 6 | 124 | 24 | 1,835 | 15 |
| Space science and applications | 192 | 111 | 1,145 | 40 | 1,936 | 358 | 186 | 112 | 207 | 4,287 | 1,326 |
| Physics and astronomy | 11 | 108 | 926 | ..... | 1,047 | 133 | ..... | ..... | 59 | 2,284 | 101 |
| Life sciences | 99 | 2 | 2 | ..... | 1 | 133 | 6 | ..... | 28 | 271 | 21 |
| Planetary exploration | 23 | ..... | ..... | ..... | 81 | 38 | ..... | ..... | 29 | 171 | 832 |
| Space applications | 59 | 1 | 217 | 40 | 807 | 54 | 180 | 112 | 91 | 1,561 | 372 |
| Technology utilization | 1 | 7 | 6 | 1 | 10 | 1 | 10 | 2 | 12 | 50 | 3 |
| Aeronautics and space technology | 51 | 15 | 181 | ..... | 134 | 1,077 | 1,920 | 1,687 | 119 | 5,184 | 161 |
| Aeronautics | 5 | ..... | 3 | ..... | 19 | 963 | 1,391 | 1,310 | 71 | 3,762 | 3 |
| Space | 46 | 15 | 178 | ..... | 115 | 114 | 529 | 377 | 48 | 1,422 | 158 |
| Tracking and data advanced systems | ..... | ..... | ..... | ..... | 29 | ..... | ..... | ..... | 3 | 32 | 82 |
| SPACE FLIGHT, CONTROL, AND DATA COMMUNICATIONS | 1,675 | 1,037 | 522 | ..... | 733 | 73 | 22 | 65 | 194 | 4,321 | 433 |
| Space production and operational capability | 619 | 126 | ..... | ..... | ..... | ..... | ..... | ..... | 22 | 767 | 6 |
| Space transportation operations | 1,056 | 911 | 522 | ..... | 100 | 73 | 22 | 65 | 120 | 2,869 | ..... |
| Space and ground network communications and data systems | ..... | ..... | ..... | ..... | 633 | ..... | ..... | ..... | 52 | 685 | 427 |
| Subtotal, direct workyears | 2,772 | 1,567 | 2,730 | 46 | 2,892 | 1,534 | 2,169 | 2,015 | 584 | 16,309 | 2,020 |
| CENTER MANAGEMENT AND OPERATIONS SUPPORT | 437 | 515 | 520 | 61 | 707 | 487 | 666 | 576 | 839 | 4,808 | 1,437 |
| Total, full-time workyears | 3,209 | 2,082 | 3,250 | 107 | 3,599 | 2,021 | 2,835 | 2,591 | 1,423 | 21,117 | ..... |
| Other than full-time | 113 | 90 | 100 | 13 | 99 | 115 | 93 | 125 | 135 | 883 | ..... |
| Total, work years | 3,322 | 2,172 | 3,350 | 120 | 3,698 | 2,136 | 2,928 | 2,716 | 1,558 | 22,000 | 3,457 |

[1] JPL is staffed by Cal. Tech. The operating costs for NASA activities are borne by the R&D and Space Flight, Control and Data Communications appropriations, except for the lease or purchase of administrative aircraft and the purchase of passenger motor vehicles, which are funded from this appropriation in the NASA Hqtrs budget.

## SECTIONAL ANALYSIS

OF H.R. 5154, A BILL TO AUTHORIZE APPROPRIATIONS TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION FOR RESEARCH AND DEVELOPMENT, SPACE FLIGHT CONTROL AND DATA COMMUNICATIONS, CONSTRUCTION OF FACILITIES, AND RESEARCH AND PROGRAM MANAGEMENT, AND FOR OTHER PURPOSES

### TITLE I

*Section 101*

*Subsections (a), (b), (c) and (d)* would authorize to be appropriated to the National Aeronautics and Space Administration funds, in the total amount of $7,531,400,000, as follows: (a) for "Research and development," a total of 10 program line items aggregating the sum of $2,450,100,000; (b) for "Space flight, control and data communications," a total of 3 line items aggregating the sum of $3,600,300,000; for (c) "Construction of facilities," a total of 17 line items aggregating the sum of $150,000,000; and (d) for "Research and program management," $1,331,000,000 of which, $1,000,000 is authorized for the National Commission on Space established pursuant to Title II of this Act. Subsection (d) would also authorize to be appropriated such additional or supplemental amounts as may be necessary for increases in salary, pay, retirement, or other employee benefits authorized by law.

The category "Space flight, control and data communications" is a new section which separates the operational aspects of the Space Transportation System and tracking and data from the research and development aspects. This category was used for the first time in the fiscal year 1984 Appropriation Act, Public Law 98–45.

*Subsection 101(e)* would authorize the use of appropriations for "Research and development" and "Space flight, control and data communications" without regard to the provisions of subsection 101(h) for: (1) items of a capital nature (other than the acquisition of land) required at locations other than NASA installations for the performance of research and development contracts; and (2) grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities. Title to such facilities shall be vested in the United States unless the Administrator determines that the national program of aeronautical and space activities will best be served by vesting title in any such grantee institution or organization. Moreover, each such grant shall be made under such conditions as the Administrator shall find necessary to insure that the United States will receive benefit therefrom adequate to justify the making of that grant.

In either case, no funds appropriated for "Research and development" and "Space flight, control and data communications" may be used for the construction of a facility in accordance with this

subsection, the estimated cost of which, including collateral equipment, exceeds $500,000, unless the Administrator notifies the Speaker of the House, the President of the Senate and the specified committees of the Congress of the nature, location, and estimated cost of such facility.

*Subsection 101(f)* would provide that, when so specified and to the extent provided in an appropriation act, (1) any amount appropriated for "Research and development," "Space flight, control and data communications," or for "Construction of facilities" may remain available without fiscal year limitation, and (2) contracts for maintenance and operation of facilities, and support services may be entered into under the "Research and program management" appropriation for periods not in excess of twelve months beginning at any time during the fiscal year.

*Subsection 101(g)* would authorize the use of not to exceed $35,000 of the "Research and program management" appropriation for scientific consultation or extraordinary expenses, including representation and official entertainment expenses, upon the authority of the Administrator, whose determination shall be final and conclusive.

*Subsection 101(h)* would provide that of the funds appropriated for "Research and development," "Space flight, control and data communications," and "Research and program management," not in excess of $100,000 per project (including collateral equipment) may be used for construction of new facilities and additions to existing facilities, and for repair, rehabilitation, or modification of facilities. This section also provides that not in excess of $500,000 per project of "Research and development" and "Space flight, control and data communications" funds may be used for any of the above for unforeseen programmatic needs.

*Section 102*

Section 102 would authorize upward variations of the sums authorized for the "Construction of facilities" line items (other than facilities planning and design) of 10 percent at the discretion or the Administrator or his designee, or 25 percent following a report by the administrator or his designee to the Committee on Science and Technology of the House of Representatives and the Committee on Commerce, Science and Transportation of the Senate on the circumstances of such action, for the purpose of meeting unusual cost variations. However, the total cost of all work authorized under these line items may not exceed the total sum authorized for "Construction of facilities" and subsection 101(c), paragraphs (1) thorugh (12).

*Section 103*

Section 103 would provide that not more than one-half of 1 percent of the funds appropriated for "Research and development" and "Space flight, control and data communications" may be transferred to and merged with the "Construction of facilities" appropriation, and, when so transferred, together with $10,000,000 of the funds appropriated for "Construction of facilities," (other than the funds appropriated for facilities planning and design pursuant to paragraph (13) of Section 101(c)), shall be available for the construc-

tion of facilities and land acquisition at any location if the Administrator determines (1) that such action is necessary because of changes in the aeronautical and space program or new scientific or engineering developments, and (2) that deferral of such action until the next authorization Act is enacted would be inconsistent with the interest of the Nation in aeronautical and space activities. However, no such funds may be obligated until 30 days have passed after the Administrator or his designee has transmitted to the Speaker of the House, the President of the Senate and the specified committees of Congress a written report containing a description of the project, its cost, and the reason why such project is in the national interest.

*Section 104*

Section 104 would provide that, notwithstanding any other provision of this Act—

(1) no amount appropriated pursuant to this Act may be used for any program deleted by the Congress from requests as originally made to either the House Committee on Science and Technology or the Senate Committee on Commerce, Science and Transportation,

(2) no amount appropriated pursuant to this Act may be used for any program in excess of the amount actually authorized for this particular program by subsections 1(a), 1(b) and 1(d), and

(3) no amount appropriated pursuant to this Act may be used for any program which has not been presented to either such committee,

unless a period of 30 days has passed afer the receipt by the Speaker of the House, the President of the Senate and each such committee of notice given by the Administrator or his designee containing a full and complete statement of the action proposed to be taken and the facts and circumstances relied upon in support of such proposed action.

*Section 105*

Section 105 would express the sense of the Congress that it is in the national interest that consideration be given to geographical distribution of Federal research funds whenever feasible and that the National Aeronautics and Space Administration should explore ways and means of distributing its research and development funds whenever feasible.

*Section 106*

This section would provide for the procurement of structural spares and the critical skills for installation of electrical, mechanical, and fluid systems thereby maintaining production readiness for a fifth orbiter vehicle.

*Section 107*

This section directs the National Aeronautics and Space Administration to continue and to enhance research and development activities in the area of space remote-sensing. The Administrator is specifically authorized and encouraged to conduct basic and applied

research on space remote-sensing, to develop space remote-sensing technologies and techniques, including those needed for monitoring the Earth and its environment, and to conduct such research and development in cooperation with other private and public research entities, including those of the Department of Commerce which are conducting and should continue to perform applications research in the area of space remote-sensing.

*Section 108*

Section 108 would express the intent of Congress that Government expenditures in supporting the development of prop fan technology be repaid by firms in the aircraft manufacturing industry when successful products employing that technology are produced by such firms. To this end, this section directs the Administrator to submit to Congress within 60 days of enactment, a plan for the payment to the Administration of royalities by firms in the aircraft industry with respect to any such products that are developed by them.

*Section 109*

Section 109(a) would amend section 102 of the National Aeronautics and Space Act of 1958, as amended, by adding a new subsection (c) that would required NASA to seek and facilitate the fullest commercial use of space. This provision encourages NASA to pursue aggressively all areas of space commercialization and to establish a focal point within the agency for space commercialization activities.

Section 109(b) would amend section 102(d)(1) of the National Aeronautics and Space Act of 1958, as amended (and as redesignated by section 109(a) of this Act), to establish as an objective of the United States aeronautics and space activities the expansion of knowledge of the Earth and of phenomena in the atmosphere and space. This section directs NASA to expand its attention and activities in Earth sciences.

*Section 110*

This section would amend the National Aeronautics and Space Act of 1958, as amended, by adding a new section 311 which would allow the Administrator of NASA to transfer title to personal property that has been on loan to an academic institution or nonprofit organization for at least two years. The Administrator would have to first certify that (1) the property is being used for a purpose consistent with the use intended when it was first loaned, and (2) NASA will no longer need that article.

## TITLE II

*Sec. 201* sets forth the purposes of Title II, to establish a National Commission on Space to assist the United States in defining long range goals for the civilian space program.

*Sec. 202* sets forth the Congressional findings.

*Sec. 203* would provide for the establishment of, within 90 days of enactment of this Act, a bipartisan National Commission on Space, to be composed of 14 Members selected by the President, the Ad-

ministrator of NASA, and ex officio and advisory Members appointed pursuant to Sec. 203(b)(1) and (2). Members appointed are to be individuals who by reason of their background, education, training, or experience, will contribute to the articulation of a long range agenda for U.S. civilian space activity. The President will designate a Chairman and the Administrator of NASA will serve as Vice Chairman who will perform the Chairman's functions in the Chairman's absence.

*Sec. 203(a)(2)* would provide for payment to the Commission Members appointed by the President at an annual rate of basic pay under Sec. 5332 of Title 5, U.S. Code, for grade GS–18 of the General Schedule for each day, including travel time, during which the members are engaged in the performance of the Commission's work. Travel expenses would be provided on a per diem basis, pursuant to Sec. 5703 of Title 5, U.S. Code. Receipt of payment by Members of the Commission under this section does not confer status as officers or employees of the United States.

*Sec. 203*(b)(1) would provide for the appointment by the President of representatives from various departments and agencies to serve on the Commission in an ex-officio capacity.

*Sec. 203(b)(2)* would provide for the appointment of Congressional advisors to the Commission.

*Sec. 203(b)(3)* would provide that ex officio and advisory members appointed under this section shall be entitled to reimbursement for travel expenses incurred while in the performance of the duties of the Commission but would otherwise not be entitled to compensation.

*Sec. 203(c)* would provide for the appointment and compensation of personnel by the Commission. The Chairman would be responsible for the assignment of duties and supervision of personnel, and the use and expenditures of funds available to the Commission.

*Sec. 203(d)* would authorize, to the extent permitted by law, the Commission to secure information from Federal executive departments, agencies, or independent instrumentalities, which shall cooperate with the Commission by furnishing such information to the extent permitted by law and upon request of the Chairman.

*Sec. 203(e)* would authorize the Commission to hold public hearings, initiate surveys and undertake other appropriate activities in discharging its responsibilities under this Act.

*Sec. 203(f)* would provide for the termination of the Commission's activities 60 days following the submission of its plan required by Sec. 204(c) of this Act.

*Sec. 204(a)* sets forth the functions of the Commission, to formulate an agenda for U.S. civilian space activity identifying long range goals, opportunities, and policy options for civil space activity for the next twenty years. The section would provide for certain considerations to be taken into account by the Commission. Based on an analysis of the Commission's findings, the Commission would develop options and recommendations for a long range civilian space policy plan.

*Sec. 204(b)* would provide for the inclusion in the Commission's plan, to the extent appropriate, estimates of costs and time schedules, institutional requirements, and statutory modifications necessary to implement the Commission's recommendations.

*Sec. 204(c)* would provide for the submission of the Commission's long range plan to the President, the Senate and the House of Representatives, within one year following the Commission's establishment.

*Sec. 205* would define commission as the National Commission on Space as provided in Sec. 203 of the Act.

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## Cost and Budget Data

The bill will authorize appropriations for fiscal year 1985 in the amount of $7,531,400,000. In accordance with the requirements of Rule XIII, Clause 7, of the rules of the House of Representatives, the Committee's estimate for the next five years of NASA budget request is as follows:

| Fiscal year: | |
|---|---|
| 1985 | $7,531,400,000 |
| 1986 | 7,914,000,000 |
| 1987 | 8,337,000,000 |
| 1988 | 8,757,000,000 |
| 1989 | 9,172,000,000 |

These estimates do not include provisions for any new program or program augmentation that may be recommended nor do they include any provisions for administrative adjustments that may be required.

## Effects of Legislation on Inflation

In accordance with Rule XI, Clause 2(1)(4) of the Rules of the House of Representatives this legislation is assessed to have no adverse long-run inflationary effects on prices and cost in the operation of the national economy. NASA expenditures are labor intensive, with approximately 85 percent of spending directly for jobs and the remainder for materials. NASA employs about 22,000 civil servants and supports about 109,000 contractor employees, plus about 4,300 support services contractors. Assuming a multiplier effect of 2.5, the total, short-run employment effect on the United States' economy is about 336,000 jobs. This represents less than one-half of one percent of the total civilian labor force in the United States—too small to have a significant national effect, although there could be some specific cases of industry and regional employment and price changes influenced by NASA expenditures.

The most significant economic effects of NASA spending are long-run productivity advances from new technologies developed for the space and aeronautics programs. Many NASA sponsored advances in air and space and transportation, communications satellites, remote sensing satellites, and other innovations have improved the productive capacity of industry and stimulated the development and growth of many new businesses. These expanded business opportunities have and are expected to continue to stimulate more productive, non-inflationary private sector economic growth and job creation.

Although it is difficult to assess the results of the various macroeconomic studies of the effects of NASA spending GNP, it is apparent from analyses done by the Midwest Research Institute,

Mathematica, Inc., and others, that NASA high technology R&D expenditures have returned more to the economy in substantial and long-lasting productivity gains than has been spent. Since these gains are through spinoff commercial advances, they are "extra" returns above and beyond the primary goal of NASA programs: the successful completion of the various R&D mission assignments to meet public sector needs. Therefore, any gains which show positive economic returns in the long-run indicate a non-inflationary, significant return to the citizens of the United States.

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## Changes in Existing Law Made by the Bill, As Reported

In compliance with clause 3 of rule XIII of the Rules of the House of Representatives, changes in existing law made by the bill, as reported, are as follows (existing law proposed to be omitted is enclosed in black brackets, new matter is printed in italic, existing law in which no change is proposed is shown in roman:

* * * * * * *

## National Aeronautics and Space Act of 1958

## TITLE I—SHORT TITLE, DECLARATION OF POLICY, AND DEFINITIONS

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### DECLARATION OF POLICY AND PURPOSE

Sec. 102. (a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provisions be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 201(e).

*(c) The Congress declares that the general welfare of the United States requires that the National Aeronautics and Space Administration (as established by title II of this Act) seek and encourage, to the maximum extent possible, the fullest commercial use of space.*

[(c)] *(d)* The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge *of the Earth and* of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment.

[(d)] *(e)* The Congress declares that the general welfare of the United States requires that the unique competence in scientific and engineering systems of the National Aeronautics and Space Administration also be directed toward ground propulsion systems research and development. Such development shall be conducted so as to contribute to the objective of developing energy- and petroleum-conserving ground propulsion systems, and of minimizing the degradation caused by such systems.

[(e)] *(f)* The Congress declares that the general welfare of the United States requires that the unique competence in scientific and engineering systems of the National Aeronautics and Space Administration also be directed toward the development of advanced automobile propulsion systems. Such development shall be conducted so as to contribute to the achievement of the purposes set forth in section 302(b) of the Automotive Propulsion Research and Development Act of 1978.

[(f)] *(g)* The Congress declares that the general welfare of the United States requires that the unique competence of the National Aeronautics and Space Administration in science and engineering systems be directed to assisting in bioengineering research, development, and demonstration programs designed to alleviate and minimize the effects of disability.

[(g)] *(h)* It is the purpose of this Act to carry out and effectuate the policies declared in subsections (a), (b), (c), (d), [(e), and (f).] *(e), (f), and (g).*

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## TITLE III—MISCELLANEOUS

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*DISPOSAL OF LOANED PERSONAL PROPERTY*

*SEC. 311. (a) Any Federal personal property which has been loaned by the National Aeronautics and Space Administration to any academic institution or nonprofit organization, and has been on loan to any such organization for at least two years, may be disposed of in accordance with subsection (b).*

*(b) Whenever the Administrator certifies that—*

*(1) property described in subsection (a) is being used by the organization holding such property for a purpose consistent with the use intended when the property was loanded, and*

*(2) that the Administration will no longer need that property, then the Administrator may transfer title to such property to that academic institution or nonprofit organization.*

### OVERSIGHT FINDINGS AND RECOMMENDATIONS

Pursuant to Rule XI, clause 2(1)(3)(A), and under the authority of Rule X, clause 2(b)(1) clause (3)(f), of the Rules of the House of Representatives no findings and recommendations are under consideration by the Committee on Science and Technology for inclusion in the legislative report to accompany H.R. 5154.

### CONGRESSIONAL BUDGET ACT INFORMATION

The bill provides for new authorization rather than new budget authority and consequently the provisions of section 308(a) of the Congressional Budget Act of 1974 are not applicable. No authorization for State or local financial assistance is included in the bill.

### CONGRESSIONAL BUDGET OFFICE—COST ESTIMATE

1. Bill number: H.R. 5154.

2. Bill title: The National Aeronautics and Space Administration Act of 1985.

3. Bill status: As ordered reported by the House Committee on Science and Technology, March 20, 1984.

4. Bill purpose: The bill authorizes the appropriation of $7,530 million for the National Aeronautics and Space Administration for fiscal year 1985 and establishes a National Commission on Space. The authorization includes $2,820 million for the production and operations of the space shuttle, $150 million for development of a space station, $2,300 million for other research and development activities, and $781 million for the space tracking system. The bill also includes $150 million for construction of facilities and $1,330 million for research and program management. Also authorized are such sums as may be necessary for increases in employee benefits as authorized by law. The amounts authorized are $39 million above the President's 1985 budget request for NASA and approximately $333 million above the 1984 appropriations for NASA.

As established in this bill, the National Commission on Space would formulate a long range plan for the civilian space program

and submit the plan to the President and the Congress within twelve months of being established. The commission would be composed of 15 members appointed by the President and representatives of various government agencies. The bill authorizes $1 million for the activities of the commission. The authorization for the commission ends 60 days after the report is submitted.

5. Estimated cost to the Federal Government:

[By fiscal years, in millions of dollars]

| | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|
| Estimated Authorization Levels: | | | | | |
| Function 250—Civilian Space | 6,844 | | | | |
| Function 400—Aeronautics | 687 | | | | |
| Function 920—Pay Raises | 33 | | | | |
| Total | 7,564 | | | | |
| Estimated Outlays: | | | | | |
| Functions 250—Civilian Space | 5,078 | 1,490 | 258 | 17 | 1 |
| Functions 400—Aeronautics | 448 | 185 | 47 | 4 | 3 |
| Functions 920—Pay Raises | 31 | 2 | | | |
| Total | 5,557 | 1,677 | 305 | 21 | 4 |

Basis of Estimate: The authorization levels are the amounts specified in the bill, plus an estimated $33 million for pay increases in fiscal year 1985 as authorized by the bill. The estimate of outlays assumes that all funds authorized will be appropriated prior to the beginning of fiscal year 1985 and that spending will reflect historical patterns.

6. Estimated cost of State and local governments: None.

7. Estimate comparison: None.

8. Previous CBO estimate: None.

## Oversight Findings and Recommendations, Committee on Government Operations

No findings or recommendations on oversight activity pursuant to clause 2(b)(2), rule X, and clause 2(1)(3)(D), rule XI, of the Rules of the House of Representatives have been submitted by the Committee on Government Operations for inclusion in this report.

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## Committee Recommendations

A quorum being present, the Committee approved the bill by a roll call vote (31–7).

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## NASA Recommendations

This is a National Aeronautics and Space Administration legislation item approved with the exceptions noted in this report by the Office of Management and Budget, as indicated by the following letters:

Hon. Thomas P. O'Neill, Jr.,
*Speaker of the House of Representatives,*
*Washington, D.C.*

Dear Mr. Speaker: Submitted herewith is a draft of a bill, "To authorize appropriations to the National Aeronautics and Space Administration for research and development; space flight, control, and data communications; construction of facilities; and research and program management; and for other purposes," together with the sectional analysis thereof.

Section 4 of the Act of June 15, 1959, 73 Stat. 75 (42 U.S.C. 2460), provides that no appropriation may be made to the National Aeronautics and Space Administration unless previously authorized by legislation. It is a purpose of the enclosed bill to provide such requisite authorization in the amounts and for the purposes recommended by the President in the Budget of the United States Government for fiscal year 1985. For that fiscal year, the bill would authorize appropriations totaling $7,491,400,000, to be made to the National Aeronautics and Space Administration as follows:

(1) for "Research and development," amounts totaling $2,400,100,000;

(2) for "Space flight, control and data communications," amounts totaling $3,600,300,000;

(3) for "Construction of facilities," amounts totaling $160,000,00; and

(4) for "Research and program management," $1,331,000,000.

In addition, the bill would authorize such sums as may be necessary for fiscal year 1986, i.e., to be available October 1, 1985.

The enclosed draft bill follows generally the format of the National Aeronautics and Space Administrative Authorization Act, 1984 (P.L. 98–52). However, the bill differs in substance from the prior Act in several respects.

First, subsections 1(a), 1(b), 1(c), and 1(d), the authorizations for the four NASA appropriation accounts, differ in the dollar

amounts and in some of the line items for which authorization to appropriate is requested.

Section 1(b) "Space flight, control and data communications," is a new category for space transportation operations which at first used in the FY 1984 HUD-Independent Agencies Appropriation Act, (P.L. 98–45).

Second, in sections 1(c), (e), and (h), the limitations on minor facility project funding limits have been raised to account for inflation over the past ten years.

Third, in addition to providing authorization of appropriations in the amounts recommended by the President in his Budget for fiscal year 1985, the bill also would provide authorization for such sums as may be necessary for fiscal year 1986. It is specified that all of the limitations and other provisions of the bill applicable to amounts appropriated pursuant to section 1 shall apply in the same manner to amounts appropriated pursuant to section 6.

Fourth, section 7 is a new section which would amend the National Aeronautics and Space Act of 1958 to allow the Administrator of NASA to give title to personal property loaned by NASA to academic institutions or nonprofit organizations, once NASA is sure that it no longer needs that property.

Finally, the last section of the draft bill, section 8, has been changed to provide that the bill, upon enactment, may be cited as the "National Aeronautics and Space Administration Authorization Act, 1985," rather than "1984."

Where required by section 102(2)(C) of the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4332(2)(C)), and the implementing regulations of the Council on Environmental Quality, environmental impact statements covering NASA installations and the programs to be funded pursuant to this bill have been or will be furnished to the Committee on Science and Technology, as appropriate.

The National Aeronautics and Space Administration recommends that the enclosed draft bill be enacted. The Office of Management and Budget has advised that such enactment would be in accord with the program of the President.

Sincerely,

JAMES M. BEGGS, *Administrator.*

## MINORITY VIEWS

### NASA FY 1985 Authorization Bill

The House Committee on Science and Technology has traditionally been a strong supporter of space programs. The committee has been pleased with the unparalleled success of the U.S. civilian space program. Recent achievements by NASA have continued this history. The space shuttle has captured the imagination of the American people. The NASA budget request for Fiscal Year 1985 will not only continue support of these programs, but allows for some spectacular new initiatives, such as the space station, the Mars Geoscience Climatology Orbiter, and the Upper Atmospheric Research Satellite. We hope to continue funding support of these programs.

However, the federal government is faced with a $200 billion deficit for fiscal year 1985. Everything added over the request level will increase this deficit even more. It should be noted that the Republican members of the subcommittees offered to accept any responsible suggestions on how to keep the budget at the President's request level while reordering priorities within this total. This approach was not accepted by the majority. Since the NASA authorization bill for FY 1985 is $40 million over the request level, we cannot support this proposed budget.

Larry Winn, Jr.
Bob Walker.
Joe Skeen.
Alfred McCandless.
Herbert H. Bateman.
Judd Gregg.
Claudine Schneider.
F. James Sensenbrenner, Jr.



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